5000-CRO

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HICKOK

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INSTRUCTION MANUAL
for
MODEL CRO-5000

FULLY TRANSISTORIZED
OSCILLOSCOPE

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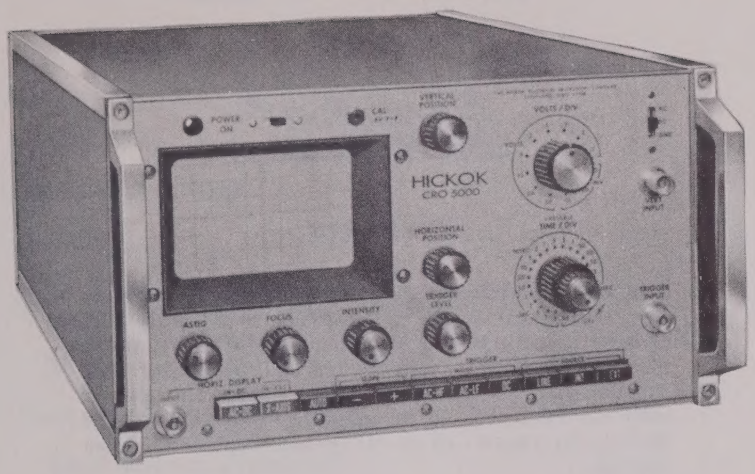

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This warranty does not apply to any of our products which have been repaired or altered by unauthorized persons, or which have been subject to misuse, negligence, or accident, or which have had the serial number altered, effaced or removed. Neither shall the warranty apply where a warranty registration card has not been properly completed and returned to us promptly after purchase. This warranty is in lieu of all other warranties whether expressed or implied.

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19120-158

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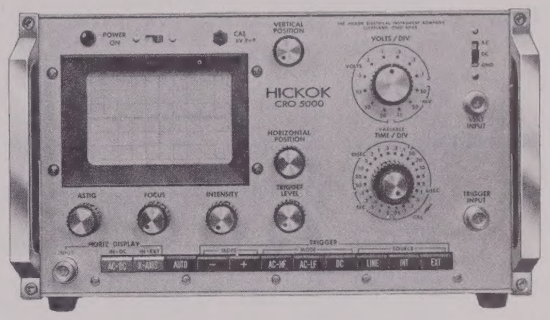
GENERAL INFORMATION

The Model CRO5000 is a versatile, rugged and compact professional oscilloscope utilizing solid state circuitry exclusively for maximum reliability. It is designed for the display and accurate measurement of both complex and simple wave forms, with response extending from DC to over 50MHz. The Model CRO5000 may be either rack or bench mounted and removable covers allow easy access to the circuitry for calibration and troubleshooting purposes.

The unit features a 25 MHz bandwidth (to -3dB point), calibrated vertical sensitivity, calibrated sweep speeds, positive triggering characteristics, and a delay line in the vertical amplifier to permit viewing of the entire leading edge of fast rise pulses. The CRT features include a flat face, small spot size and excellent intensity characteristics. The CRT is recessed to reduce glare. Layout of panel controls combines simplicity of operation with logical grouping and retractile elevation stand permits raising the front of the unit for added viewing ease.

The extraordinary performance capability of the CRO5000 makes it an ideal general purpose high frequency oscilloscope for use in development laboratories, production testing, and precision electronic servicing work.



Model CRO5000 Oscilloscope

SECTION I
SPECIFICATIONS

Cathode Ray Tube:

Type	Brimar SE4D
Unblanking	DC coupled
Accelerating Potential	3.8 kV
Usable Viewing Area	4.8 cm x 8 cm
Phosphor	P31
Graticule	High precision photographically etched divided into a 6 x 10 div. grid. 1 major division is equal to .8 cm. Major divisions are divided into 5 equal minor divisions. Line width of graticule is .004"

Power Supplies:

Line Voltage	117V AC, 60 Hz nominal. Limits on input 105 to 125 VAC, 50 to 65 Hz.
Power Consumption	Approximately 32 watts.
Internal Supplies	All internal supplies are regulated.

Mechanical:

Dimensions	Width 11-1/4", height 6-7/8" from table top, depth 19" (including handles).
Weight	24 pounds

Calibrator Output:

Output	.6V peak to peak ±1% square wave.
Frequency	approximately 1 kHz.

Vertical Deflection System:

Deflection Factors	10mV/Div to 50V/Div in 12 steps, 1, 2, 5 sequence. Accuracy is ±3%.
Positioning	Vertical Positioning control allows for a ±15 division range and the amplifier is designed to recover from deflections within the range with negligible distortion of the wave form.
Input	Selector Switch provides for AC or DC coupled input or grounded amplifier input to establish the ground reference. Impedance is 1 megohm ±1% shunted by 30 pF ±1 pF.
Bandwidth	When DC coupled, at all deflection factors the upper -3dB point will exceed 25 MHz. Lower frequency response is flat to DC. When AC coupled, the low frequency - 3dB point will be 5 Hz. The high frequency response will remain the same as above. The roll-off characteristic is essentially Gaussian for best pulse response.
Wave Form Aberrations	Less than 3% of applied wave form or 1/10 of a division, whichever is greater.
Maximum Input	DC plus AC peak, not greater than 600V
Overload Protection	The 10mV/Div range is protected for input signals up to 50V DC plus AC peak. Other ranges protected for 600V DC plus AC peak decreasing to 1000 to 1 overload at 20 MHz.
Delay Line	Provides for a minimum of 50 ns of base line prior to start of a displayed pulse when triggered internally, to permit viewing of the leading edge of fast rise wave forms.

Horizontal Deflection System:

Sweep	50 nsec/Div to 2 sec/Div in 24 ranges, in a 1, 2, 5 sequence. Calibrated accuracy for fastest 21 ranges is ±3%. Sweep speed is continuously variable between ranges.
"Sweep Delay"	The sweep wave form may be delayed up to 40 divisions by means of the multi-turn Horizontal position control, allowing the operator to obtain full screen presentation of selected portion of the input wave form or pulse train.
X-Axis Amplifier	AC or DC coupled input. Bandwidth is DC to over 5 MHz when DC coupled and 5 Hz to over 5 MHz when AC coupled. The input sensitivity is 200mV ±5%. Input impedance is 1 megohm ±5% shunted by approximately 30 pF.

Trigger and Trigger Requirements:

Source	Either external, internal or line frequency signals may be selected.
Mode	AC-HF (high frequency), AC-LF (low frequency) and DC. AC-HF inserts a filter which rejects signal components below 3 kHz; AC-LF inserts a low pass filter which rejects signal components above 10 kHz.

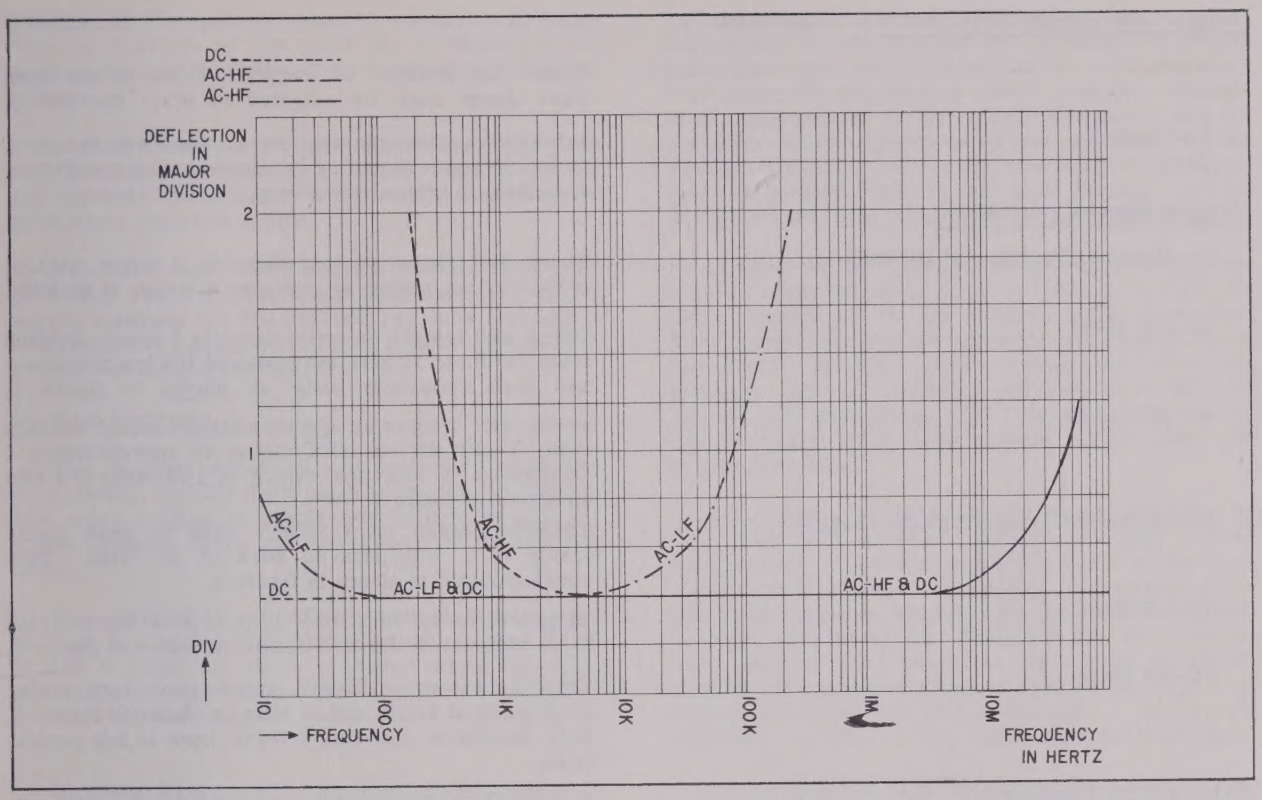


Figure 1. Typical Trigger Response Curves Trigger Source - Internal

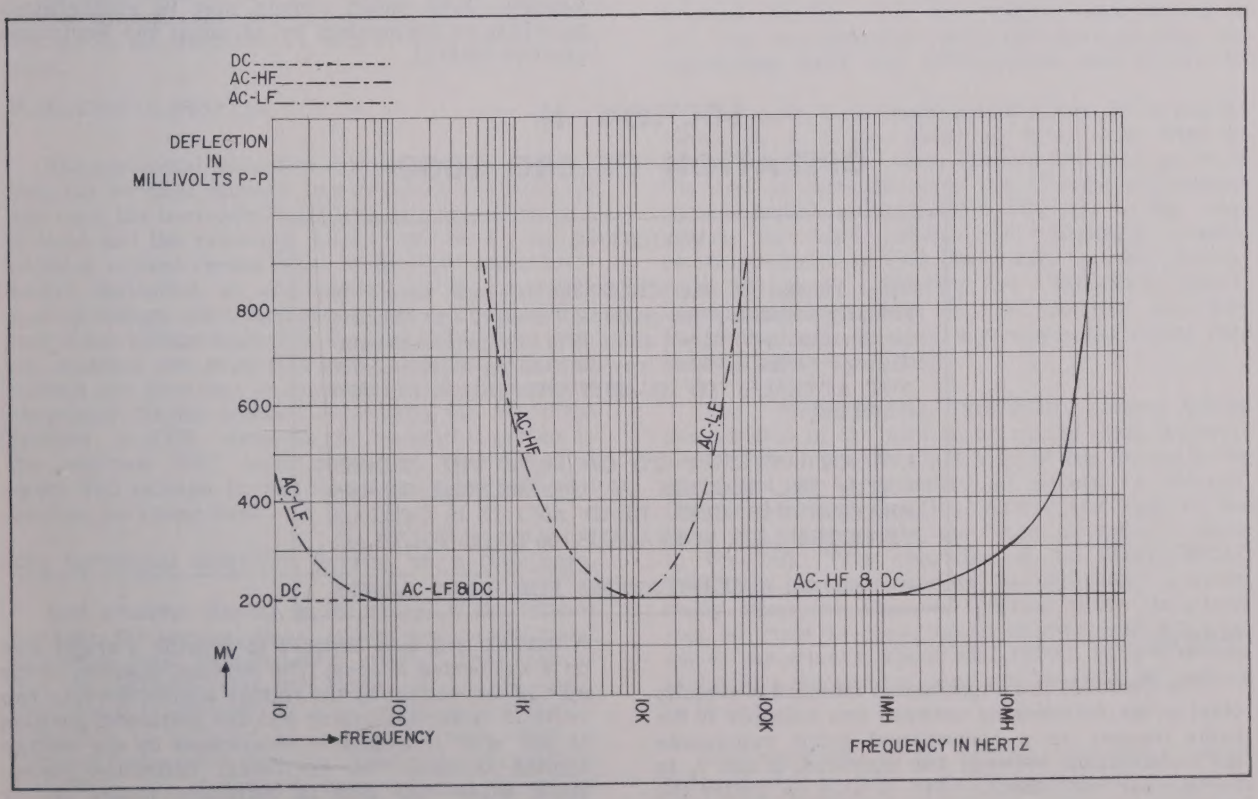


Figure 2. Typical Trigger Response Curves Trigger Source - External

Trigger and Trigger Requirements: (Continued)

Slope	Either the positive or negative slope of the input wave form may be selected to start the sweep.
Automatic	Provides a free-running sweep whenever the input to the Trigger circuitry is absent or of insufficient amplitude to trigger the sweep.

Trigger Signal Rquirements:

Int. (Internal Triggering) DC Mode	Sweep will trigger on approximately 1 minor division of deflection, rising to 1 major division at 40 MHz.
AC-LF Mode	Sweep will trigger on approximately 1 minor division from 50 Hz to 10 kHz and rising at the low frequency and high frequency ends as shown in figure 1.
AC-HF Mode	Sweep will trigger on approximately 1 small division from 7 kHz to 10 MHz rising to approximately 1 division at 40 MHz and rising to 1 division at 1 kHz as shown in figure 1.
Ext. (External Triggering) DC Mode	Triggers sweep on a 200mV peak to peak input, rising to 1 volt peak to peak at 40 MHz. This characteristic is shown in figure 2.
AC-LF Mode	Triggers sweep on 200mV peak to peak input, rising to .5 volts at 10 Hz and 15 kHz as shown in figure 2.
AC-HF Mode	Triggers sweep on 200mV peak to peak input, rising to .5 volts at 1 kHz and 25 MHz as shown in figure 2. Note maximum External trigger input is 2 V peak to peak.
Trigger Input Impedance:	1 megohm ±5% shunted by approximately 20 pF. General trigger uncertainty is less than 5 nanoseconds. High speed signals may be synchronized to eliminate uncertainty by adjusting the Horizontal position control.

SECTION II
OPERATION OF CRO 5000

WARNING

Upon receipt of the CRO5000, the unit should be visually inspected for physical damage. The shipping carton should be saved since it is designed to prevent damage to the cathode ray tube during shipment. DO NOT ATTEMPT TO RE-SHIP WITHOUT A PROPER CARTON.

DO NOT ATTEMPT TO OPERATE THE CRO5000 UNTIL THE SECTION OF THIS MANUAL ON OPERATION HAS BEEN READ AND IT IS CERTAIN THAT THE LINE VOLTAGE IS 105 TO 125 VOLTS AC.

REFER TO SPECIFICATIONS FOR INPUT LIMITS.

General.

The CRO5000 is an instrument intended to visually display the relationship between two voltages in the same manner as a conventional graph represents the relationship between two numbers, x and y, in rectangular coordinates. The x axis is called the Horizontal axis, and the y axis the Vertical axis. A cathode ray tube is used to provide a bright spot on a calibrated screen. The vertical position of the spot is determined by the voltage applied between two vertical deflection plates and the horizontal position of the spot is similarly determined by the voltage applied between two horizontal deflection plates. Since these two sets of deflection plates are at right angles to each other and independent, the

location of the spot corresponds exactly to the location on a graph of the point (x, y) where x is the applied horizontal voltage, and y is the applied vertical voltage.

In most cases, the voltages applied vary with time and are repetitive so that the bright dot traces out continuously the dynamic relationship and visually presents a complete graph.

Basically, three sets of front panel controls are provided: Vertical axis, Horizontal axis, and power supply controls for the cathode ray tube so that the brightness and shape of the spot may be adjusted for the convenience of the operator.

Vertical controls.

The vertical sensitivity is controlled by means of a switch, and the front panel is marked to indicate how much voltage is required to deflect the spot one major division of the ruled screen of the cathode ray tube.

The VERTICAL POSITION control provides for moving the spot (or displayed graph) up and down. It has a range of about plus and minus three full screens. Its use enables the operator to observe portions of the display which might otherwise be off screen.

In cases where a DC component of the input voltage is not desired, a slide switch is provided to insert a capacitor between the input voltage and the vertical display system. This same switch also allows the input voltage to be disconnected, thus providing zero volts input.

HORIZONTAL SYSTEM:

The horizontal deflection system is more complex than the vertical since it has two basic functions. In one case, the horizontal deflection is a linear function of time and the resulting display will be a graph of vertical voltage versus time. In the other case, horizontal deflection is proportional to an externally applied voltage and a displayed graph will be observed only if the voltage applied to the horizontal and vertical systems are related to each other. Two red push buttons are provided to determine the function of the horizontal display system: depressing the red button marked X-AXIS connects the horizontal system to the adjacent BNC input connector. Depressing it again will release it, and the horizontal system will function as a time base.

The horizontal deflection system as a time base.

For a useful display on the screen of the cathode ray tube, the vertical signal applied and the horizontal deflection must be coherently related. This insures that the deflected spot will trace and retrace itself, reinforcing brightness. To accomplish this, horizontal deflection is initiated by a trigger pulse which is internally generated from the voltage used for vertical deflection, or, if desired, from the line voltage or from some external voltage source. Three push buttons are provided to determine the trigger source: depressing the one marked INT presents the trigger pulse generator with a sample of the vertical signal; depressing the one marked LINE presents a sample of the line voltage to the trigger generator, and depressing EXT allows a signal connected to the TRIGGER INPUT BNC connector to drive the trigger pulse generator. One of the three buttons must be depressed for operation of the horizontal time base.

Because of the complexity of wave forms that may be observed, it is often necessary to filter the signal presented to the trigger pulse generator. Three push buttons are provided for this purpose: depressing AC-HF inserts a high pass filter; depressing AC-LF inserts a lot pass filter but also blocks DC; depressing DC removes all filters. One of these three buttons must be depressed for proper operation.

The trigger pulse generator itself is biased by the TRIGGER LEVEL control and this control consequently picks the amplitude level of its input signal where a pulse is generated. The trigger pulse generator operates whenever its input signal crosses the bias point set by the TRIGGER LEVEL control. The operator may start the time base on either positive or negative slope crossings by means of depressing either the button marked + or the one marked - . One or the other must be depressed.

In the absence of pulses from the trigger pulse generator, the time base may be started by a free-running oscillator simply by depressing the button marked AUTO. For low trigger rates (below 60 Hz) this may interfere with normal triggering, and depressing again the AUTO button will release it.

The time base does not free-run. It is started either by a trigger pulse or by a pulse from the AUTO oscillator. Once started, the rate at which the spot is deflected from left to right is governed by the switch marked TIME/DIV and by the concentric red knob. When this VARIABLE control is fully clockwise, the sweep rate is read directly from the panel. Rotating the VARIABLE control counterclockwise from its CAL position will slow the sweep rate to allow any convenient sweep rate between calibrated points.

The HORIZONTAL POSITION control allows the position of the spot to be varied along the horizontal axis from the right side of the screen to the equivalent of 40 divisions off screen to the left. Counterclockwise rotation moves the spot to the left, and consequently, the "start of sweep" moves to the left. This operation of the HORIZONTAL POSITION control provides the equivalent of sweep delay since the observed portion of the time base can be made to occur up to 40 time units after the sweep has started. The HORIZONTAL POSITION control also positions the spot with the X-AXIS function is in use.

The remainder of the controls are used to adjust the cathode ray tube voltages so that spot intensity, size, and focus are optimized. These controls are

marked ASTIG, FOCUS and INTENSITY and normally interact to some extent. Full clockwise rotation of the INTENSITY control will cause spot size to increase and some background illumination when the spot is off-screen. This is an aid in finding the spot and subsequently adjusting the VERTICAL POSITION or other controls to obtain a display.

Operational check.

To check the CRO5000 for proper operation, plug power cord into 117V AC line. Note that the instrument case is connected to third wire ground. Set the front panel controls as follows:

VERTICAL POSITION	Centered
VOLTS/DIV	100 mV
AC-DC-GND	GND
HORIZONTAL POSITION	FULL CCW
TIME/DIV	.5 mSEC
VARIABLE	FULL CW
TRIGGER LEVEL	Centered
Depress INT	
Depress DC	
Depress +	
Depress AUTO	
X-AXIS should be out	
INTENSITY	FULL CW
ASTIG	Centered
FOCUS	Centered

With the controls set as above, turn the power on and allow three minutes for warmup. A bright horizontal line should be observed.

Connect the CAL output to VERT INPUT connector and set the slide switch to DC. Center the trace by adjusting the VERTICAL POSITION control. Adjust FOCUS, ASTIG and INTENSITY controls for clean and sharp display. Rotate HORIZONTAL POSITION control until the start of the sweep occurs at the first ruled line of the graticule. The display should be as in Figure 3. To obtain familiarity with the CRO5000, the controls may be manipulated as desired and the effects observed.

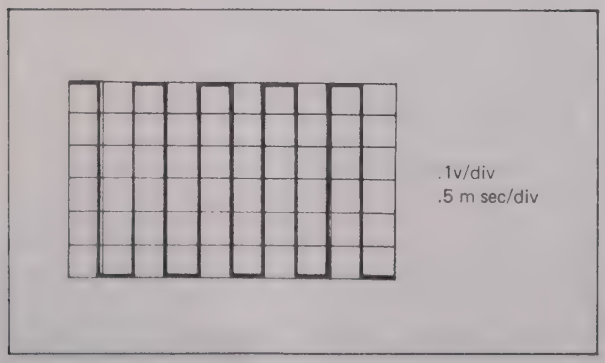


Figure 3. Calibrator Display

Use of probes.

Attenuator probes are frequently used to reduce resistive and capacitive loading of the circuit under test. The Hickok type 16970-87 or any standard probe which is capable of adjusting to a 30 pF scope input capacity can be used. When making measurements with a proble, multiply the observed amplitude by the probe attenuation factor. The Hickok 16970-87 has a factor of 10.

To assure the accuracy of high frequency and pulse measurements, probe adjustment is necessary. To make this adjustment, proceed as follows:

1. Set the VOLTS/DIV switch to 10mV, and slide switch to DC, and connect the probe to the CAL output connector.
2. Set the TIME/DIV switch to .5mSEC and adjust the trigger controls for a stable display.
3. Adjust the probe for sharp rise and best flatness of the positive peak. Refer to figure 4.

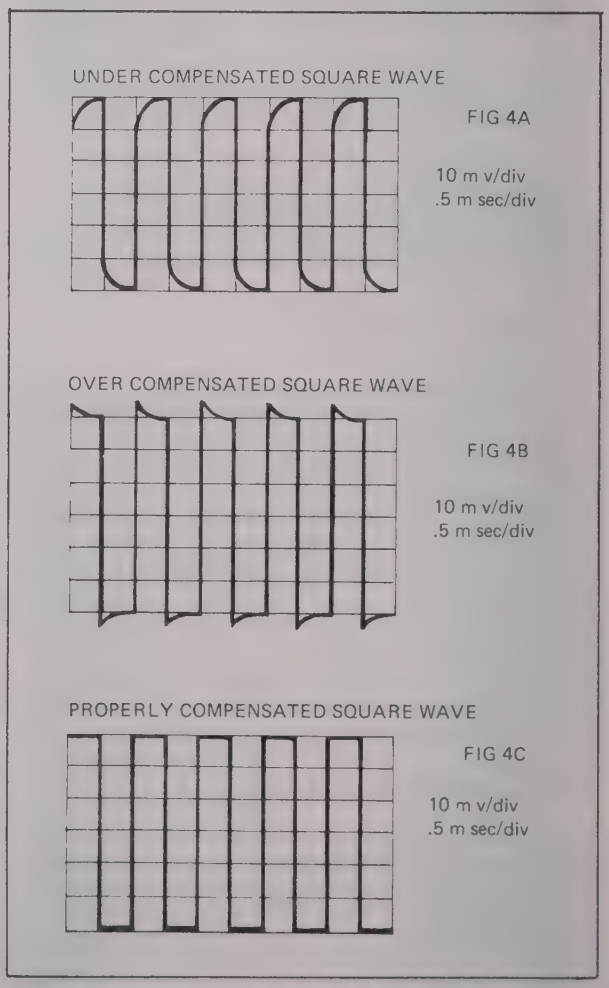


Figure 4. Probe Squarewave Compensator

SECTION III
APPLICATIONS

In this section of the instruction manual the basic procedures and techniques for making measurements with the CRO5000 will be described. This section is not meant to be a comprehensive text covering all possible uses of the CRO5000, but is intended to familiarize the user with some of the basic applications and techniques. Familiarity with the techniques and the operation of the controls will enable the operator to apply the CRO5000 to a wide variety of applications.

TYPICAL VOLTAGE MEASUREMENTS.

AC Component Measurement.

Set the Vertical input selector switch to the AC position. In this position, only the AC components of the signal are displayed on the CRT. (It should be noted, however, that if the frequency of the AC component is very low the DC position should be used. If the trace is off screen use the Position control in conjunction with the VOLTS/DIV switch to obtain a trace on screen.)

To make peak to peak measurements of the AC component of the wave form, perform the following steps. The AUTO button should be depressed and the sweep set to 1ms/Div, or some other more appropriate rate, dependent upon the frequency of the viewed wave form.

a. Adjust the VOLTS/DIV switch for the largest on-screen display.

b. Depress the External, DC and + buttons and adjust the TRIGGER LEVEL for a stable, locked, display.

c. Adjust the sweep rate so that several cycles of the wave form are displayed.

d. Use the VERTICAL and HORIZONTAL POSITION controls to position the wave form to a point on the CRT where the amplitude can be easily determined. As an example, position the wave form so that one of the negative peaks coincides with one of the lower horizontal graticule lines and the positive peak occurs on the divided center vertical line.

e. Measure the vertical deflection in divisions and multiply this result by the VOLTS/DIV setting (and by the probe attenuation factor, if used). As an example of this method, assume that 5.2 divisions of deflection were used, that the VOLTS/DIV switch is set to .1 VOLTS/DIV and that 10:1 probe was used. Thus, the calculation of the voltage amplitude would be as follows:

Vertical deflection in divisions		VOLTS/DIV setting		Probe attenuation factor	=	Volts Peak to peak
5.2	X	.1	X	10	=	5.2 volts p-p

This example is demonstrated in figure 5.

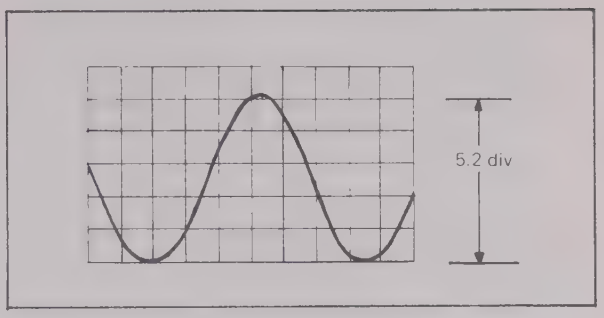


Figure 5. Measurement of AC Component Amplitude

Measurement of DC Voltage Level.

To measure the DC level or a DC voltage level at a given point on a wave form, use the following procedure:

a. Set the TIME/DIV to 1MS/DIV and depress the AUTO button.

b. Adjust the VOLTS/DIV switch so that the voltage applied to the input connector is no more than six times the VOLTS/DIV switch setting.

c. Set the AC-DC-GND switch to GND and, using the VERTICAL POSITION control, position the trace so that it coincides with the bottom horizontal graticule line. This point will be used as the zero voltage reference. (Note if the signal to be measured is negative in sense, one of the top horizontal graticule lines should be used.) Do not move the VERTICAL POSITION control after it has been set.

d. Set the AC-DC-GND switch to DC.

e. Adjust the sweep rate and trigger controls for a stable trace if there is an AC component present.

f. Using the HORIZONTAL POSITION control, position the point on the wave form to be measured on the center vertical graticule line.

g. Measure the distance from the base reference line to the point on the wave form which crosses the center vertical graticule line and convert this reading to a voltage by the following relationship:

Deflection in division	X	VOLTS/DIV setting	X	Probe attenuator	=	Volts DC

Typical Time Measurements

To measure the time duration of a pulse or the period of a wave form, the following procedure is used.

1. Measurement of pulse duration.

Generally, when measuring the width of a pulse the measurement is made from the 10% of amplitude points. Since the procedure for measuring pulse width and pulse duration differ only in the reference point on the wave form, the more complex or pulse width measurement will be outlined.

a. Adjust the VOLTS/DIV switch for a deflection near full scale and note the exact amplitude in divisions.

b. Divide this measurement by 10 and, using the VERTICAL POSITIONING control, position the trace bottom exactly this amount under the center horizontal graticule line. As an example: assume that the deflection height is 4.5 divisions. Dividing this by 10 yields .45 divisions or 2-1/4 minor divisions. Position the bottom edge of the wave form from this distance below the graticule horizontal center line. Do not adjust the VERTICAL POSITION control after this point.

c. Set the TIME/DIV switch so that the pulse width is no more than 10 times the TIME/DIV switch setting.

d. Using the HORIZONTAL POSITION control, position the leading edge of the pulse to a convenient vertical graticule line, at the point where it crosses the horizontal center line, at the left-hand side of the screen.

e. Measure the distance (in major divisions) between the point where the leading edge crosses the center horizontal graticule line and the trailing edge crosses the center horizontal graticule line.

f. Multiply this distance by the time indicated by the setting of the TIME/DIV switch to obtain the pulse width in units of time.

2. Measuring the period of periodic wave forms.

a. Adjust the VOLTS/DIV and VERTICAL POSITION control to give a trace centered about the horizontal center line of the graticule.

b. Adjust the sweep rate and trigger controls to obtain one or more cycles of the wave form on screen.

c. Using the HORIZONTAL POSITION control, position the wave form so that it crosses the junction point of a vertical graticule line on the left-hand side of the screen and the center horizontal graticule line. Note the direction in which the wave form crosses the center horizontal graticule line.

d. Measure the distance (in major divisions) from the junction point described above to where a comparable point of the next cycle of the wave form again crosses the center horizontal graticule line in the same direction as in d. above.

e. Multiply this distance by the setting of the TIME/DIV switch to obtain the time duration of the period (T). This technique is demonstrated in Figure 6.

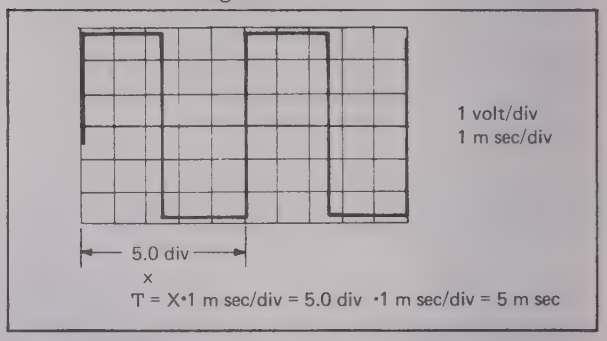


Figure 6. Measurement of Period of Wave Form

Measurement of the Time Difference of Two Pulses

In the application of this technique it is necessary to have an external trigger source time related to the pulses and the two pulses must be frequency related. In this example it will be assumed that the first occurring pulse can be used as a source for External Trigger. (The Trigger Input requires a minimum input of 200mV peak-to-peak.)

a. Connect measurement Pulse Source A to both the VERT. INPUT and the TRIGGER INPUTS of the CRO5000.

b. Set the VOLTS/DIV switch so that the input signal which is applied to the VERT. INPUT connector provides approximately six vertical divisions of wave form display. Adjust the VERTICAL POSITION control so that the pulse amplitude 50% point coincides with the center horizontal graticule line.

c. Set the Trigger controls to EXT, DC + and TRIGGER LEVEL for a stable locked trace.

d. Using a HORIZONTAL POSITION control, position the wave form so that it crosses a junction point of the center horizontal graticule line and convenient vertical graticule line. Record this point.

e. Remove Pulse Source #1 from the VERT. INPUT and connect Pulse Source "B" to the VERT INPUT of the CRO5000. Be sure to leave Pulse Source "A" connected to the TRIGGER INPUT. Do not touch the HORIZONTAL POSITION control and TRIGGER LEVEL.

f. Set the VOLTS/DIV switch to obtain approximately six divisions of display and adjust the VERTICAL POSITION so that the 50% point of the pulse amplitude coincides with the horizontal center line of the graticule.

g. Measure in major divisions from the point where the Pulse A first crossed the center line to the point where the Pulse B crosses the center horizontal line.

h. To obtain the delay between the two pulses, multiply the distance measured in step g by the setting of the TIME/DIV switch.

SECTION IV
THEORY OF OPERATION AND CIRCUIT DESCRIPTION

In this section of the instruction manual the operation of the various sections of the circuit is described. A simplified operational block diagram is presented in figure 7 and a brief description of each section is given below to explain the general operation of each circuit, then a detailed description of each circuit is presented.

Block Diagram Description

Power supply:

The power supply provides all operating voltages for the CRO5000. All supplies are regulated by the line input regulator and further regulation is provided for the -20 volt, + 20 volts and the -800 volt supplies.

Vertical amplifier:

Basically the vertical amplifier consists of the following:

The input coupling network, an attenuator, the input amplifier, the delay line driver and the final amplifier. The input amplifier splits the phase of the input signal and amplifies it to provide a differential signal to the rest of the amplifier.

Trigger pick-off amplifier:

The trigger pick-off amplifier applies an amplified sample of the vertical input signal to the trigger circuitry. The signal for the trigger is sampled at the input to the delay line driver amplifier.

Time base circuitry:

The time base generator provides an accurate voltage ramp for the horizontal deflection system. The time base ramp may be started by signals either from internal or external sources.

Trigger circuitry:

The trigger circuitry converts the input signal to a pulse which causes the gating multivibrator to change states, turning the time base generator on and the blanking off.

Horizontal amplifier:

The input to the horizontal amplifier is selected from either the output of the time base generator or the horizontal display input. The input selector is split in phase by the input amplifier and is amplified to provide push-pull drive for the horizontal deflection plates.

Hold-off circuitry:

The hold-off circuit samples the output of the horizontal amplifier during sweep to determine when the time base generator should be turned off and the blanking turned on.

Cathode ray tube:

The cathode ray tube used in the CRO5000 is a 4 inch, flat-face tube with a 4.8cm x 8cm usable area. The tube is designed for minimum spot size with high intensity and minimum center to edge defocusing in both axles.

Calibrator circuit:

The calibrator circuit in the CRO5000 is an astable multivibrator running at approximately 1 Hz. The output of the astable is used to drive a switching transistor, which through a divide, provides a fast rise time squarewave with a minumum of DC offset and high amplitude stability.

The following is a detailed description of the operation of each circuit in the CRO5000. While reading through the description of a particular circuit, refer to the proper schematic diagram located at the end of this instruction manual and the block diagram in figure 7.

Circuit Description

Line input regulation:

Regulation of the power supplies in the CRO5000 is achieved by keeping the input voltage to the power transformer constant. This is done by limiting the peak input line voltage by a predetermined valve. The peak limiting circuit consists of a power transistor (Q101), four steering diodes (CR101 through CR104) in series with the primary winding of the transformer. A voltage comparison amplifier and secondary feedback winding controls the peak limiter.

In operation, during the positive half cycle of the line input, the current path is through CR102, Q101 and CR103. During the negative half cycle the current path is through CR101, Q101 and CR104. The point at which Q101 stops conducting is determined by comparison of the voltage from a secondary feedback winding (#3-5) and a zener voltage (Q107) through a differential amplifier. When the feedback voltage exceeds the zener voltage, Q105 begins to conduct, drawing the base of Q101 out of conduction. When Q101 is not conducting the current path to the primary winding is essentially open-circuited and no higher voltage will be developed across the primary.

The voltage feedback from the secondary winding is obtained by rectifying the capacitively filtering the output of the rectifier. Thus, the feedback voltage is derived from a peak detector and is directly related to the peak voltage at the primary. The end of the

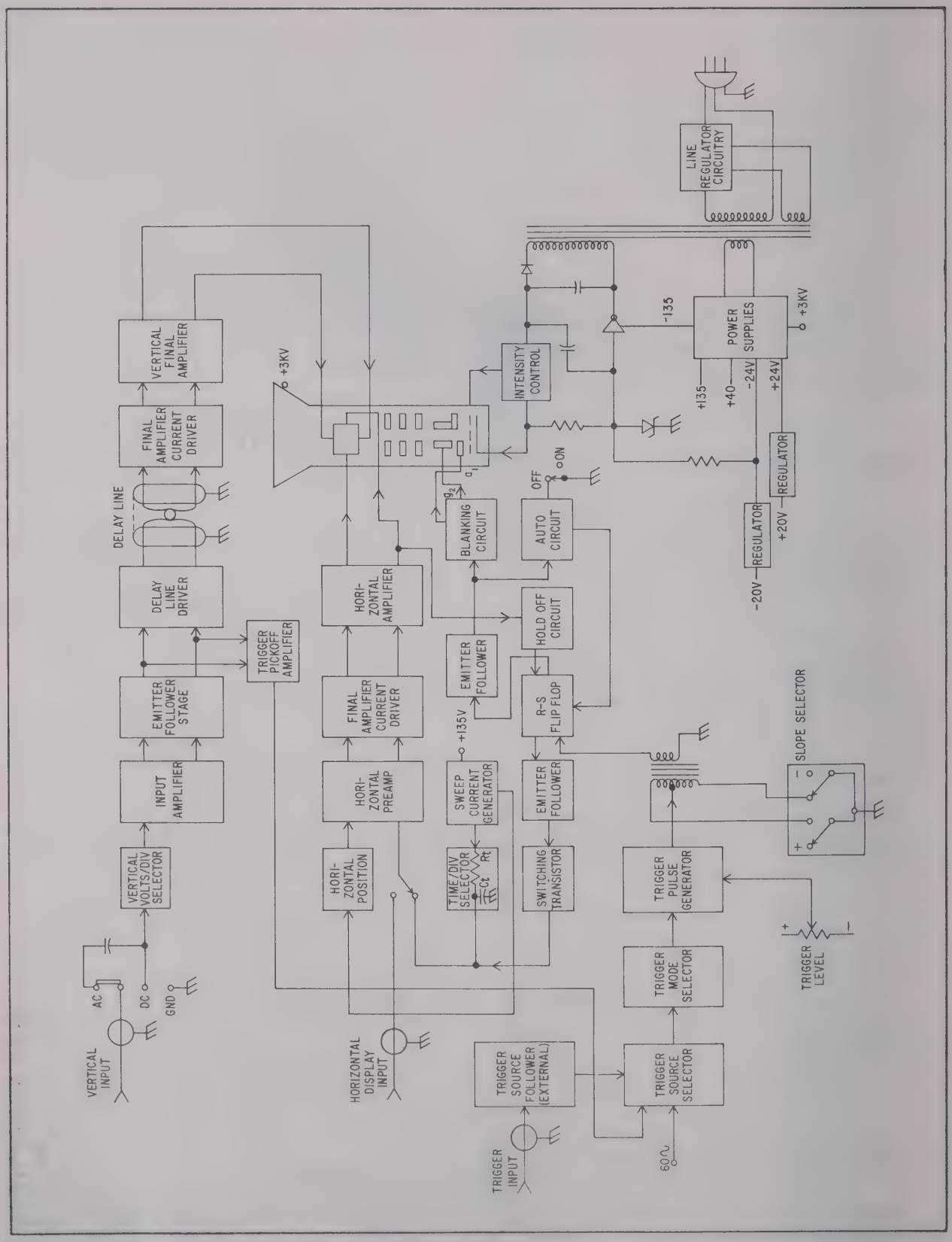


Figure 7. Operational Block Diagram

conduction region of Q101, and thus the maximum peak voltage across the primary, are determined by the setting of R108, which determines the divide ratio from the feedback voltage.

Voltages derived from the secondary winding:

The power supply delivers filtered and regulated voltages of + 24, + 40, + 135, + 3000, -24 and -800 volts. Further regulation is provided for the -800, -24 and + 24 volt supplies. A -800 volts is obtained and the output of the negative high voltage regulator is used to feed the CRT circuitry. Negative 20 volts and plus 20 volts are derived from the -24 volt and + 24 volt supplies, respectively. A common power transformer, T101, supplies the input power to each of the supplies as well as heater power to the CRT.

In operation each supply is supplied by a secondary winding. The output of each winding is rectified by silicon diodes connected in a full wave configuration, and filtered by a capacitor, with the exception of the -800V and + 3kV supplies which are half wave rectified.

The -800V regulator is a bootstrap type of regulator. The output of this supply is sampled by an inverting amplifier connected to the bottom of the winding. Thus, when the output of the supply increases the output of the amplifier decreases by an equal amount, within its swing capability. The AC output of the supply is also coupled to the input of the amplifier, so the regulator will also smooth out the ripple voltage.

The + 20V and -20 supplies are taken from the outputs of simple series type regulators. These two supplies are protected from temporary short circuits. It should be noted, however, that prolonged short circuits will cause R601 and R624 to be over-dissipated and damage to these two resistors will result.

Vertical amplifier system:

Input attenuator:

The signal to be displayed is applied to the input amplifier via the AC, DC, GND switch, S302. In the DC position, the input coupling capacitor, C310, is bypassed so the input is DC coupled. In the AC position the signal must pass through C310, which blocks the DC component of the input signal. The capacitor limits the lower frequency response to approximately 5 Hz at the -3dB point. In the GND position the input circuit is disconnected from the amplifier and the amplifier input lead is grounded.

Attenuation:

After passing through the input selector the signal passes through the VOLTS/DIV switch, S301. S301 is a four section, 12 position rotary switch; the last two sections of the switch contain the attenuator networks corresponding to the .01V range through the .5 volt range. The first two sections contain a 100:1 attenuator that is cascaded with the previous attenuator as the switch goes through its last 6 ranges. The output of the last section of the switch is connected electrically to the input amplifier.

In the .01 VOLTS/DIV position of the switch the input signal is connected directly to the input amplifier. In the next five positions the individual attenuator networks are inserted in the circuit to provide the necessary divide of the input signal. The applied signal at the input of the amplifier is always .01 volt for each division of deflection obtained on the CRT.

In the last six positions of the switch a 100:1 attenuator is cascaded with each of the previous divide networks to provide for deflection sensitivities of 1 volt/div through 50V/Div.

Each of the attenuators is a frequency compensated, resistance-capacitance network that will provide a constant voltage divide over the frequency range. At the lower frequencies the divides are primarily resistive. As the frequency of the input signal increases, the divide ratio will depend more upon the values of the capacitors used to shunt the resistive divide.

The variable capacitor at the input of each divide network provides a means for adjusting the input capacity to a convenient value common to all positions of the switch. As a result of this adjustment the input impedance on any attenuator position will be held constant relative to the other positions. This is especially useful when using a probe, as it will not be necessary to readjust the frequency compensation of the probe each time the range is changed.

Input amplifier:

This stage is a source coupled, high input impedance, FET paraphase amplifier. It converts the single-ended input signal applied to the gate of Q201 to differential current signals at the drains of Q201 and Q221. The sources are "long tailed" through a current generator (Q218 and Q217) to provide for greater DC stability with respect to the junction FET parameters. The differential output is coupled into an emitter coupled, cascaded amplifier, where the signal is further amplified. The signal is then DC coupled back to the sources of the input stage to provide maximum feedback stability. The output of the input amplifier is then coupled to the emitter follower stage.

Emitter follower:

This stage of the amplifier provides isolation between stages, in that it provides a high impedance, low capacitance load on the previous stage and a low impedance output to the delay line driver stage and the trigger pickoff amplifier.

Delay line driver:

This section of the circuit is designed to provide for the gain adjustment of the whole amplifier and to provide a balanced 93 ohm per side drive for

the delay line. This is accomplished by a simple "long tailed", emitter coupled, differential amplifier working into equivalent 93 ohm load resistors.

Delay line:

The delay line provides for a signal delay of 120 nanosec, at an input impedance of 187 ohms. Since the delay line is after the trigger pick-off amplifier, the input signal will be displayed on screen 120 nsec after the trigger system has been initiated. However, because of the inherent delay in the trigger circuitry and sweep circuitry the end result will be that the signal will reach the trigger point on screen approximately 50 nsec after the sweep has been initiated on screen.

Vertical final amplifier:

The vertical final amplifier consists of two complementary feedback pairs operating as current generators into the emitters of the output transistors. The output transistors operate in grounded base configuration although biased at + 6 volts. The input impedance of the final is set to 187 ohms by precision resistors to provide proper termination of the delay amplifier.

Horizontal amplifier:

The horizontal amplifier converts the single ended sweep ramp output of the sweep generator into an amplified push-pull signal suitable for driving the horizontal deflection plates. The amplifier consists of a preamplification stage and a final amplification stage that is connected to the horizontal deflection plate leads.

The input to the preamplifier consists of two high input impedance P-channel FET transistors, connected in a "long tailed", paraphase configuration. The drains of these transistors are connected to the inputs of an emitter coupled differential amplifier. The outputs of this amplifier are fed back to the sources of the input amplifier to provide current feedback referenced to the input, yielding high DC and gain stability. The final amplifier is driven directly from the collectors of the differential amplifier.

The final amplifier consists of two complimentary feedback pairs connected differentially to a common current source. The complimentary feedback pairs are connected to the emitters of the grounded base amplifiers and provide the necessary current swing to produce the differential voltage swing required at the deflection plates.

Time Base

The time base consists of sweep trigger circuitry and ramp generation circuitry. The sweep trigger circuitry consists of the controls for mode, source, slope, level, trigger pulse generator, and gating circuits used to generate the start sweep pulse. The sweep or ramp generation circuitry consists of the switching transistor and associated R-C network, the current generator, hold-off, and blanking circuits.

Trigger circuit:

The input to the trigger circuit is selected by the source selector; either internal, external or line frequency signals may be selected. If the external mode is selected, the input signal is coupled into a high input impedance source follower. After the source has been determined it is necessary to determine the mode of coupling the trigger signal to the input of the Trigger Pulse Generator either AC-HF, AC-LF or DC coupling may be selected. In the AC-HF mode only high frequency components of the trigger signal are passed unattenuated and similarly only low frequency components will be passed unattenuated in the AC-LF mode. In the DC mode, however, all frequency components of the trigger signal, including DC, are passed.

From the mode selector the trigger signal is coupled to the input of the trigger pulse generator.

The trigger pulse generator operates as follows:

A positive going signal is applied at the base of Q515 (an emitter follower), causing the emitter to rise with it. At some point on the input voltage, as determined by the reference DC level from the LEVEL control into the opposite side of the Trigger Pulse generator, Q516 will begin to conduct. (The initial assumption of proper adjustment of the trigger level and a positive going signal require that Q516 be turned off). When this happens the voltage at the collector of Q516 will begin to fall. This will cause Q520 to become forward biased and begin to draw current, which in turn will require that Q519 give up current. This causes the voltage at the collector of Q519 to fall towards ground, and the emitter follower, Q518, will also fall. This will cause the base of Q517 to begin approaching reverse bias which in turn will cause Q517 to give up more current. This will cause Q516 to draw more current at a greater rate until the switching process is complete.

When Q520 became forward biased in the switching process, the current through the primary of T501 was changed from 0 to a current, I, in a very brief time. Thus, at the output winding of T501, a very sharp pulse will have been generated.

The polarity of the pulse out of T501 will depend upon the direction of the flux in the core. It will be noticed that there are two primaries on T501 wound in opposite directions and connected to the shape selector so that when the + button is depressed the

flux path through T501 is such that the positive pulse generated in switching will coincide with the positive slope of the trigger input wave form. When the - button is depressed the positive pulse will coincide with the negative slope of the input wave form.

The output of T501 is connected to one input of a R-S (reset-set) flip-flop. When a sweep ramp is not being generated, Q524 is off and Q525 is conducting. Therefore, a positive pulse at the base of Q523 will cause it to conduct momentarily, dropping the voltage at the collector of Q524. This voltage drop will be coupled through the zener diode Q521 to the base of Q525, tending to drive it out of conduction and thus causing the regnerative switching process to take place.

Sweep ramp generation:

The low output of Q524, at this point, is conducted through an emitter follower to the base of Q619, the Switching Transistor. This causes Q619 to be "turned off" and the timing capacitor to be charged.

A linear voltage ramp is obtained by applying a constant current from the current generator into the capacitor to satisfy the relationship $T = \frac{CV}{I}$

Blanking circuit:

The low output of Q524 is also coupled through an emitter follower, Q621, to the input of the blanking circuit. The low voltage at the base of Q614 causes the transistor to become reversed biased and the voltage at the collector to be pulled up by the momentary conduction of Q606 until it is clamped at + 78V by CR607. When the voltage at g_2 of the CRT reaches the potential at A_1, the beam is unblanked.

When the linear voltage ramp reaches the end of sweep the R-S flip-flop will be reset as explained below. This will cause the base of Q614 to be forward biased and the voltage at the collector will drop until it is clamped at + 20V by CR609 and the beam will be blanked.

The process of blanking in the CRT consists of deflecting the electron beam to the side so it will no longer pass through an aperture. This will cause the electron beam not to appear on screen. When the electron beam is unblanked, it will not be deflected and as a result will appear on screen.

Two plates, one on each side of the beam, deflect or blank the electron beam when there is a 56V difference in potential between the two plates. To unblank the beam, the potential of the two plates must be equal.

Hold-off circuit:

The hold-off circuit samples the output of the horizontal amplifier to sense the turn-off point on the sweep wave form. The hold-off circuit consists of a Schmitt trigger (Q528, 529 and 534) which is driven by an emitter follower Q577. The output of the Schmitt trigger is coupled to the reset of the R-S flip-flop, at the base of Q526. A positive output from the hold-off circuit will cause the R-S flip-flop to be reset. This causes the blanking circuit to be turned on (see preceding paragraph on the operation of the blanking circuit) and at the same time causes Q619, the sweep generator, to be forward biased, discharging the timing capacitor.

In operation, the sawtooth sampled at the collector of Q514, as it approaches saturation, connects the diode, CR508, and draws down the input to the emitter follower, Q527. As the output voltage of the follower decreases, the input transistor of the Schmitt trigger, Q528, is forward biased and regenerative switching takes place. At this point Q619 is forward biased and the timing capacitor discharged through Q619.

The sawtooth, in the process of driving the base of Q527, will cause the hold-off capacitor to be discharged. As the timing capacitor discharges the voltage at the collector of Q514 will rise to a positive voltage, close to the + 135 volt supply, causing the horizontal amplifier output to disconnect from the hold-off circuit. When this occurs the hold-off capacitor connected between the base of Q527 and ground will begin to charge positive. When the voltage at the emitter of Q527 reaches the point where Q528 is reverse biased, the Schmitt trigger switches states, uninhibiting the R-S flip-flop and allowing it to accept the trigger pulses applied on the set side. Thus, it is necessary to provide sufficient hold-off time to allow Q619 to discharge the timing capacitor completely or erratic sweep behavior and locking characteristics will be observed.

SECTION V
SERVICE PROCEDURE

As an aid to servicing your unit, photographs showing physical location of components are included in figures 16 through 25. These carry the same symbol designations as the schematics and parts list and are included in the instruction book at the end of this section.

WARNING

1. Precautions against shock should be taken when the covers are removed, as all supplies, voltages and line will be exposed.
2. In order to prevent damage to line regulator and/or operator from accidental shock, the unit should not be operated with the rear panel removed from the side frames.
3. If it is necessary to service the power supply, it should be noted that the case of Q101 is at line potential. Precautions should be taken to prevent shorting the case to ground either by contact with the side frames or through the operator. In both cases extensive damage may be the result.
4. When servicing the power supply, an isolation transformer should be used so that accidental grounding of the power line by test equipment ground does not occur.

General

Normally, the Model CRO5000 will not require service for extended periods of time; however, if service is required, it is recommended that only qualified individuals, thoroughly familiar with transistor circuit operation, undertake such service. The Hickok Electrical Instrument Company maintains a complete factory service department, backed by authorized factory repair stations, to assure prompt service for this instrument.

If it is necessary to repair the instrument in the field, it is imperative that the section covering the theory of operation be read and understood before proceeding. It is also important that a logical approach be used to localize circuit failures, as indiscriminate replacement of components could cause damage to the board or perfectly good component. The Procedure for Replacing Components in Printed Circuit Boards, outlined in figure 8, should be followed rigorously in order to prevent damage to components or printed circuit boards.

To remove cover panels

WARNING: Unit should not be plugged into power line during this procedure.

To remove the covers it is necessary to first remove the four screws holding the trim pieces to the rear panel. After the two rear panel trim pieces have been removed, four additional screws will be exposed; remove these screws and lay the panel on the bench. Next slide out the top cover and the two side covers. Carefully turn the unit over and remove the single screw near the rear-center of the bottom cover and slide the bottom cover out. Before proceeding, the rear panel should be replaced and secured with the screws to the side frames. Normal precautions against shock should be taken, since once the covers are removed, all power supplies are exposed.

Recalibration

To insure accurate measurements, the calibration of the instrument should be periodically checked. Complete calibration instructions are given in Section VI.

Visual inspection

The CRO5000 should be inspected periodically for such defects as broken connections and leads and heat damaged components. The unit should also be inspected for excessive accumulations of dust on heat dissipating elements and the dust removed.

To replace cathode ray tube

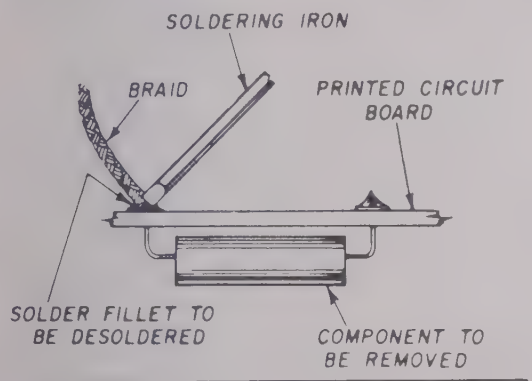
To remove and replace the cathode ray tube, use the following procedure:

1. Remove rear panel and lay it down on bench.
2. Remove the CRT anode lead, all leads from the neck of the CRT, and the rear socket connector.
3. Using a Phillips head screwdriver, remove the two screws on the left side frame mounting the CRT retaining bracket.
4. Lift the CRT assembly back and out of the unit.
5. Loosen the clamp holding the neck shield and pull the tube free of the shield assembly.

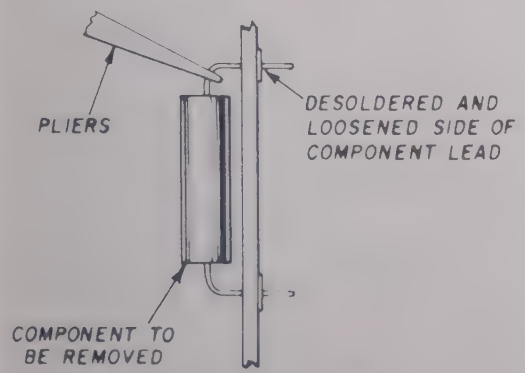
PROCEDURE FOR REPLACING COMPONENTS IN PRINTED CIRCUIT BOARDS

1. Place printed circuit in the horizontal position with the soldered side up*. Take a length of fine braid or fine stranded wire either tinned or not tinned. Braid is preferable. Dip the end of the braid in resin flux (London Chemical Co. type #77-33-TA or equivalent). Placed the fluxed end of the braid on a solder fillet of the component to be removed. Press the braid on to the fillet using the clean tip of the soldering iron. Do not overheat the board or component. Only heat the solder fillet sufficient to melt the solder. The solder will "wick" up the braided wire removing the solder from the joint. Continue this process until all leads of the component to be removed are free of solder.

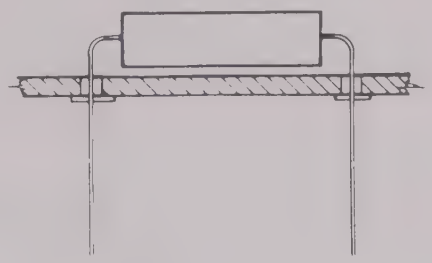
*A SOLDAPULLT desoldering tool, manufactured by Edsyn Inc., can be used in place of standard wire.



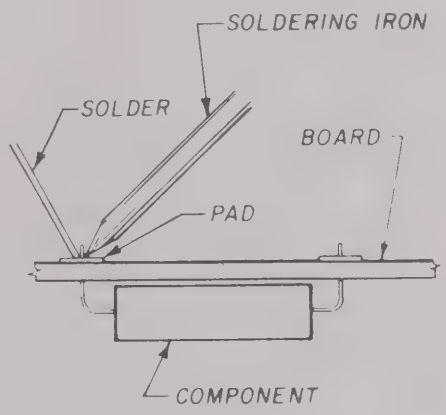
2. Using a pair of needle nose pliers "wiggle" each lead of the component to be removed to be sure it is free of the land area to which it was soldered. Place the needle nose pliers on the component lead and remove the lead. Continue the procedure with each component lead until the component is removed. Do not force the leads. If a lead can not be removed touch the lead on the soldered side of the board with the soldering tip.

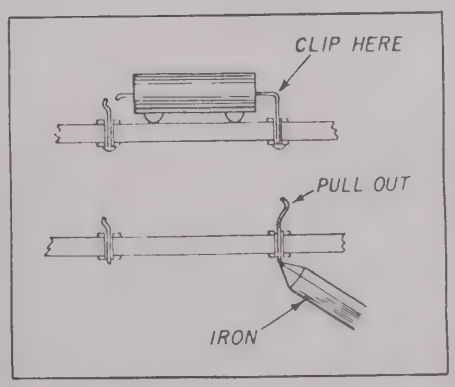


3. Bend clean tinned leads of new component and carefully insert in holes. (Do not force component. If it does not insert easily reheat pad and clean as before).



4. Hold part to board and solder leads from print side of board. Do not leave a large blob of solder on pad. The correct amount can be determined by observing other connections made in production.





Clean holes with a piece of .020 stainless steel wire by melting the solder and poking the wire through.

The above should be carefully followed or extensive damage to the printed circuit board will result.

Figure 8. Servicing Etched Circuit Boards

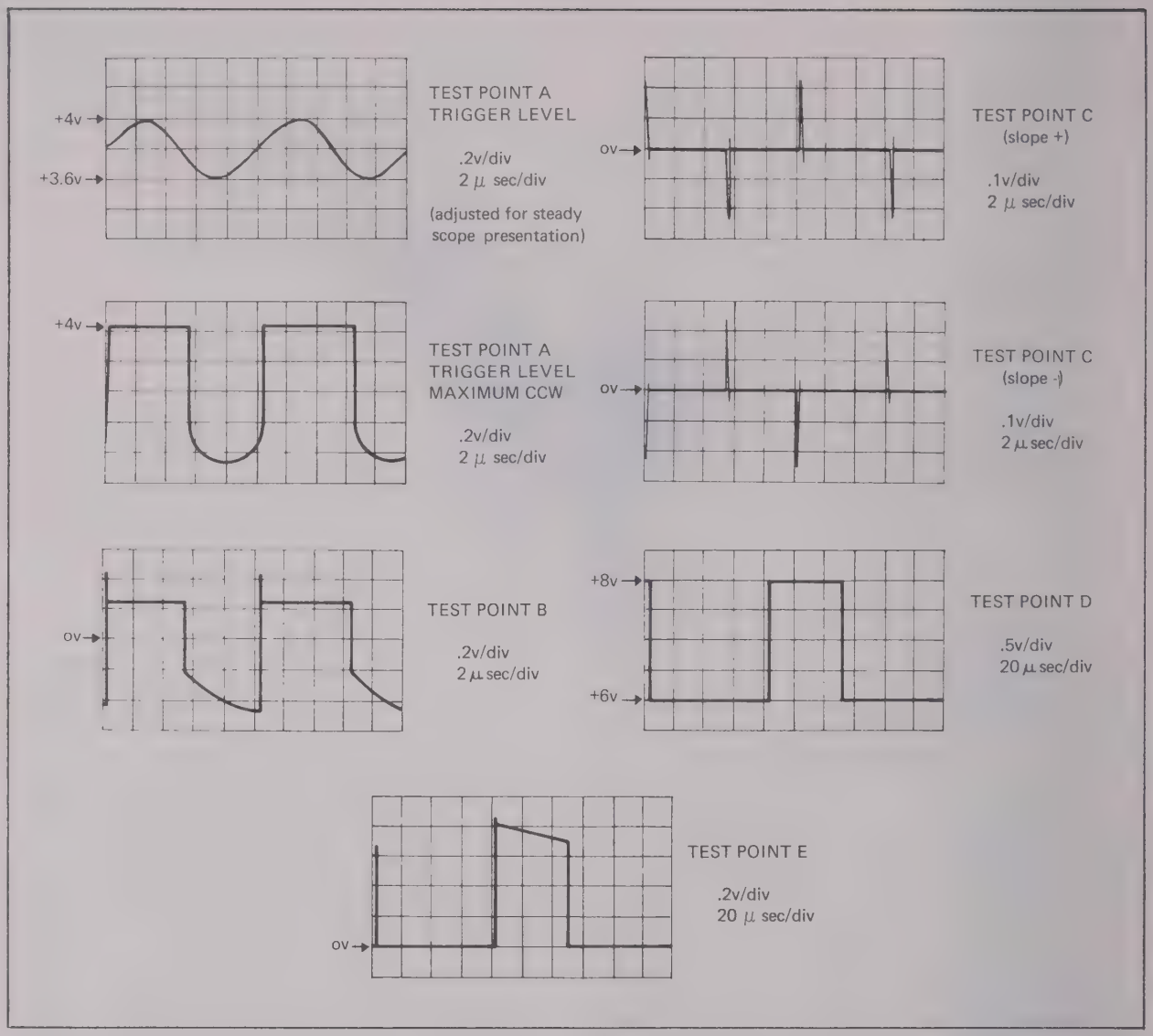


Figure 9. Wave Forms, Trigger Circuit Test Points

6. The neck shield is potted to the CRT with General Electric RTV-112 adhesive. After removabl of the neck shield from the tube the excess compound can be removed from the shield by soaking in a strong chlorinated solvent.

NOTE: The neck shield should be re-potted on the new CRT in order to provide proper clamping of the CRT.

Troubleshooting

The first step in repair of the unit should be to localize the problem to a general area of the circuitry, such as the vertical amplifier, trigger circuitry, etc. This can generally be accomplished by observation of the performance of the unit. As an aid to the localization of the problem area, it is helpful to think of the unit as divided into nine major areas of circuitry. For the CRO5000 these are as follows:

1. Trigger circuitry
2. Sweep generator
3. Blanking circuit
4. Horizontal amplifier
5. Vertical amplifier
6. Delay line
7. Power supplies
8. CRT circuitry
9. Calibrator

The Model CRO5000, as with all highly accurate instruments, will require periodic recalibration checks in order to insure a high degree of accuracy. It also should be noted that on occasion circuits out of calibration may cause apparent trouble symptoms. For

this reason, the calibration of the unit should be checked before proceeding with a detailed trouble analysis; also, a calibration check will greatly aid in localizing circuit failures. The calibration procedure is found in Section VI of this instruction book.

In the event trouble develops, it is prudent to check all the obvious possibilities first. Thus, the following should be checked:

1. The line cord is plugged in and there is power at the receptacle.

2. The fuse is good; note that the pilot lamp lights when the power switch is turned on.

3. All the front panel controls are set properly for the desired operation.

Then adjust the panel controls through their range and observe the operation in an attempt to localize the problem to a particular section of the circuitry. The normal or abnormal operation of a particular control will aid in localizing the trouble.

Since the Model CRO5000 is an extremely complex instrument, a comprehensive troubleshooting procedure is beyond the scope of this text. In general, troubleshooting an instrument can be divided into two parts: isolating or localizing the trouble to a particular circuit, and the actual location of the defective component. The first step, isolation to a particular circuit, is covered in a general manner in the paragraphs above. Reference to figure 7, the Simplified Operational Block Diagram, and the theory of operation will further aid in localizing the trouble.

After the trouble has been isolated to a particular circuit, perform a complete visual check of that circuit for faulty components. If a visual check of the circuit fails to detect the trouble, it will be necessary to check the circuit for its electrical operating characteristics. As an aid to this procedure, the voltages and wave forms at the various test points are presented at the end of this section.

Trigger circuitry

Trigger circuit troubles are indicated by an inability to lock the trace and by erratic triggering of the sweep. The first step in troubleshooting this section is to check for the presence of an input signal to the trigger circuit at the base of Q515. If a signal is present at Q515 base, then proceed to check for the proper operation of each section of the trigger circuit. Typical wave forms and voltage levels for the test points on schematic "Horizontal Board - Section A", are given in figure 9.

If no triggered trace is obtained and all sections of the trigger circuit are operational, go to the sections outlining the sweep generator and blanking circuit.

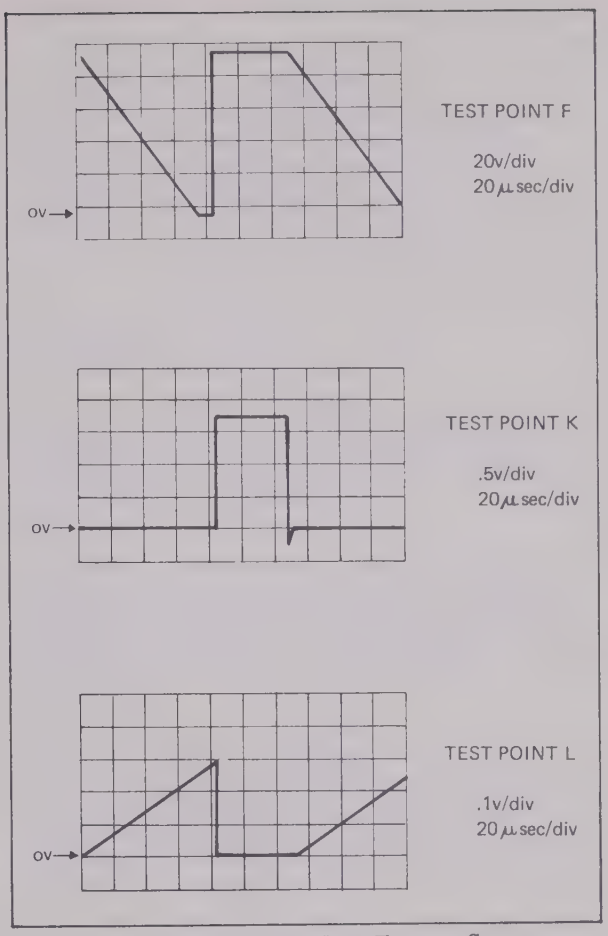


Figure 10. Sawtooth Wave Forms, Sweep Generator Circuit Test Points

Sweep generator

Troubles in the Sweep Generator are generally indicated by either large amounts of line frequency modulation in the horizontal direction or by no sweep being generated.

If line modulation is the problem the trouble can be traced to the sweep current generator which consists of the circuitry associated with Q616 and Q617. Typically, the ripple voltage at the output side of R663 is 10 to 20 mV peak to peak. Check the calibration of the sweep timing before proceeding to check for faulty components.

If the problem is apparently the lack of a generated sweep, first check at test point L. A sawtooth wave form as indicated in figure 10 should be obtained. If this wave form is found to be present check for the signal at the input of the horizontal amplifier. If, however, no sawtooth was detected at test point L check for the presence of a gating pulse at test point K. The wave form seen at this point should be similar to that shown in figure 10. If the gating pulse is present then Q619 will have to be replaced; if not, then check for the presence of the gating pulse at the base of Q618. Not detecting

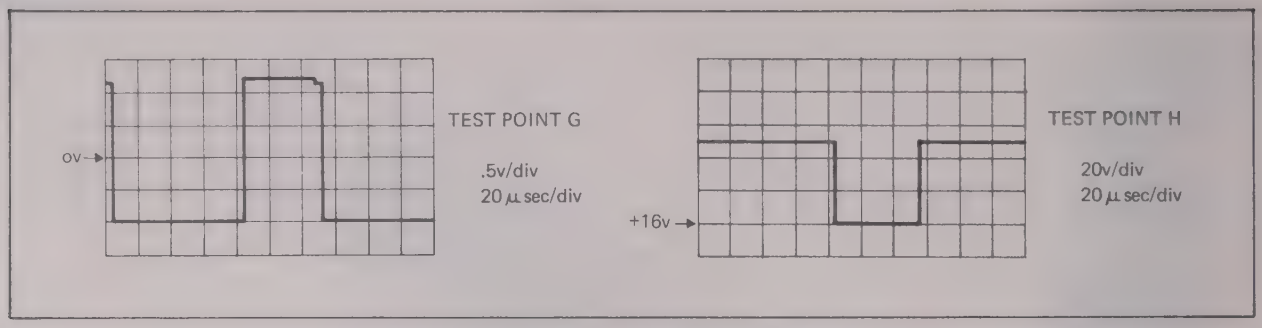


Figure 11. Wave Forms, Blanking Circuit Test Points

a gating signal at the base of Q618 indicates that the problem is located in the trigger circuitry and the procedures outlined in that section should be repeated.

Blanking circuit.

Blanking circuit problems are generally indicated by an absence of trace or by a lack of blanking. A lack of blanking will be indicated at the lower sweep speeds by a vertical trace at the start of sweep.

The CRT will be blanked when the voltage at test point H is low (approximately + 20V) and a trace should be obtained when test point H is at approximately + 78V. A typical blanking waveform is shown in figure 11.

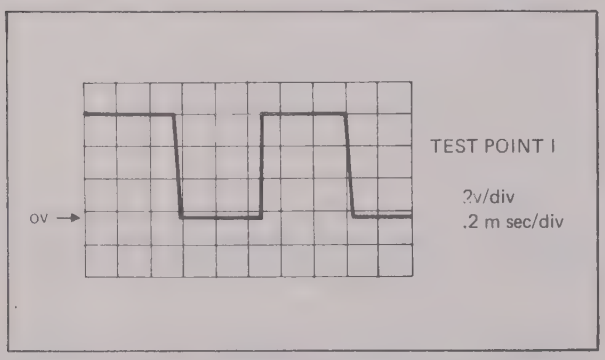


Figure 12. Wave Forms, Calibrator Circuit Test

Horizontal amplifier.

The problem of outlining a definite troubleshooting procedure for an amplifier is very complex. However, the basic problem is the same as found in troubleshooting any circuit; and that is to first isolate the problem to a particular stage and then to isolate the particular faulty component. One technique that provides very quick results in isolating the problem to a particular stage in a differential amplifier, such as used in the CRO5000, is to use a jumper to short the outputs of each stage together. To utilize this technique, it must first be determined whether the trace is centered vertically. To accomplish this, take a voltmeter and measure the potentials at the collectors of Q210 and Q213, then using the vertical positioning control, set the voltages read at the collectors of Q210 and Q213 equal to each other. Next, depress the X-AXIS button and turn the INTENSITY control fully clockwise (to maximum intensity). Then use the jumper to short the collectors of Q511 to Q514. At this point the spot should appear near the center of the graticule. If the spot does not appear, check the connectors to the horizontal deflection plates of the CRT and then check the CRT. If the spot does appear, then move the jumper to the emitters of Q511 and Q514. If the spot does not appear check Q511 and Q514. Next, move the jumper to the bases of Q519 and Q512. If the spot does not appear check the voltage levels around this section of the amplifier. Thus, it is seen that the technique consists of merely shorting the outputs of the amplifier stages together, proceeding from the output of the final to the input of the first stage. The point at which the spot does not occur indicates that the trouble lies in the previous stage.

After the trouble has been localized to a particular stage, ordinary techniques may be used for pinpointing the problem to a particular component.

Vertical amplifier

The jumper technique outlined under HORIZONTAL AMPLIFIER should also be used to isolate problems in the vertical amplifier. The points that should be shorted together are given in the following table

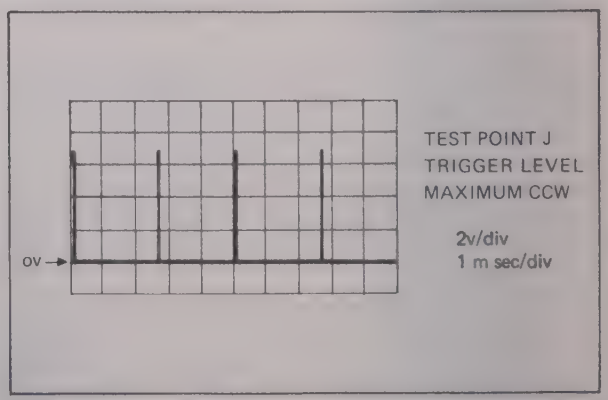


Figure 13. Wave Form, Auto Circuit Test Point

along with the stage the trouble is in if the spot does not appear. Before proceeding to use the jumper test use a volt meter and the Horizontal Position control to equalize the DC voltage at the collectors of Q514 and Q511 with X-AXIS button depressed.

TABLE I. TROUBLE SHOOTING DIFFERENTIAL AMPLIFIER

Short together	Problem localized to
Collector Q210 to collector Q213	Connections to CRT or CRT
Emitter Q210 to emitter Q213	Either Q213 or Q210
Base Q211 to base Q216	Circuitry associated with Q211, Q216, Q212 and Q215
Collector Q218 to collector Q217	Delay line - see section on delay line
Base Q218 to base Q207	Delay line driver amplifier and current generator
Collector Q203 to collector Q223	Either Q204 or Q225
Measure voltage at drain of Q201 and Q221	If more than a volt difference, check current generator and voltages at test points and then input FETs

Delay line

Ordinarily, without rough treatment, the delay line should not fail. However, if the test procedure of the previous section indicates that the trouble is in the delay line, check the external connections visually and then lift one of the input sides out of the circuit and, using an ohmmeter, check the resistance from one input side to the other. The reading should be approximately 187 ohms unless the delay line has become shorted.

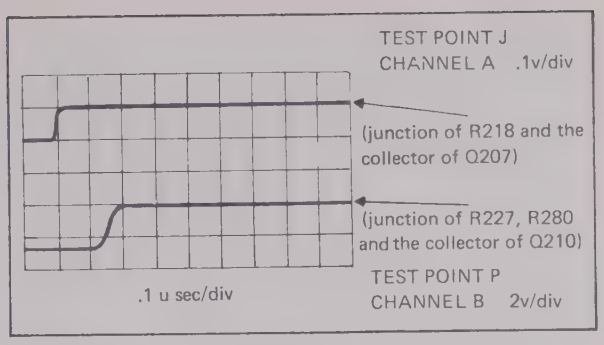

TEST POINT J
CHANNEL A .1v/div
(junction of R218 and the collector of Q207)
(junction of R227, R280 and the collector of Q210)
.1 u sec/div
TEST POINT P
CHANNEL B 2v/div

Figure 14. Wave Forms, Vertical Delay Line Test Points

If the delay line proves to be shorted, pull out a few turns of the leads out of both ends, one at a time, until the short disappears. Then redress the leads and re-install the delay line.

CAUTION: Removing the spirally wound conductor will reduce the delay time and it is recommended that a new delay line be purchased if more than 2" of lead has been removed.

Power supplies

The circuitry connected to the secondary side of the transformer is the normal type found in various types of circuitry and standard troubleshooting procedures will quickly isolate faulty components.

The circuitry on the primary side, however, must be treated with care in order to prevent damage to the operator or further damage to the circuitry. It is suggested that the line input of the CRO5000 be connected to an isolation transformer before any test measurements are made to prevent accidental grounding of the line input. A thorough understanding of the operation of the line regulator and the test voltages at point E and D given in figure 15 will greatly aid in troubleshooting the supply.

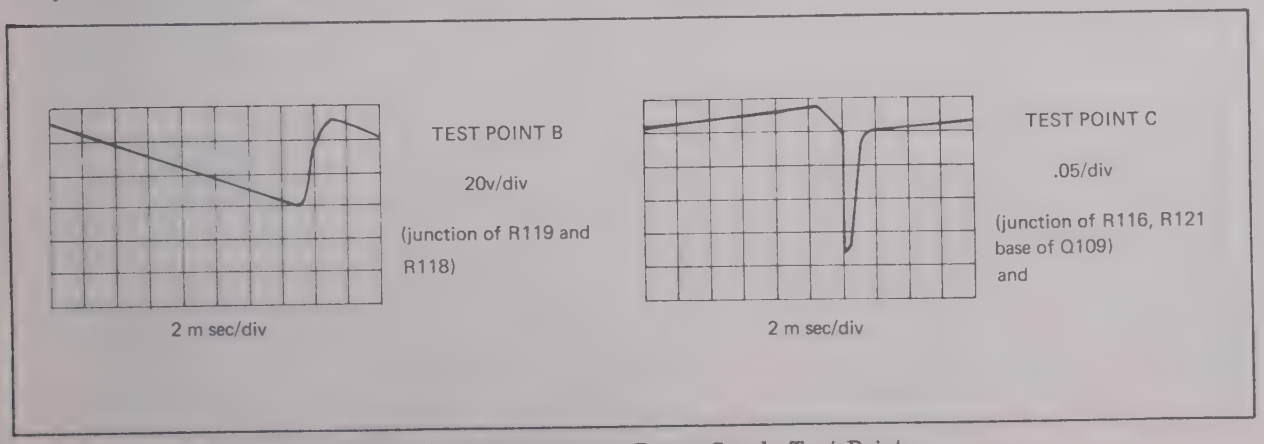


Figure 15. Wave Forms, Power Supply Test Points

Horizontal board wave forms:

The following wave forms shown in this folder were observed with an input, 100 kc sinusoidal wave, of 1 volt amplitude. The CRO5000 controls were preset as follows:

AUTO	Depressed
SLOPE	+ Depressed
DC	Depressed
INT	Depressed
TIME/DIV	5 μ sec/DIV
VOLTS/DIV	Set to 1V/DIV

Adjust trigger for steady scope presentation.

HORIZONTAL POSITION:	Adjusted so that start of sweep is at the first vertical graticule line

Make adjustments to trigger and horizontal controls as called out in the following figures.

The test scope was triggered externally from the Trigger Pulse Generator in figure 9 at the collector of Q520 to obtain the wave forms shown and from the R-S flip-flop in figure 10. The trigger control settings were as follows: EXT, negative slope, DC coupling mode. The vertical VOLTS/DIV settings and the TIME/DIV settings are as noted beside each figure. Either the ground reference line or the peak voltage is also indicated for each figure to relate the wave form to the appropriate DC level at the particular test point.

Vertical board test points:

The voltage levels for these test points are given relative to the position of the front panel Vertical Position control.

The CRO5000 front panel controls are preset as follows:

AC-DC-GND	DC
TIME/DIV	1msec/DIV
HORIZONTAL POSITION	Adjust for Center
VERTICAL POSITION	Adjust for Center
AUTO	Depressed
SLOPE	+ Depressed
MODE	DC Depressed
SOURCE	INT Depressed

ALL VOLTAGES MEASURED FROM TEST POINTS TO GROUND± EXCEPT TEST POINTS G AND H.

TABLE II. VERTICAL TEST POINT VOLTAGES

TEST POINT	VERT POSITIONING CONTROL CW	CCW	
A	+ .300V	+ .335V	
B	- .700V	- .375V	
C	+ 14.0V	+ 13.9V	
D	+ 13.7V	+ 13.8V	
E	+ 3.55V	+ 6.75V	
F	+ 6.75V	+ 3.55V	
J	+ 1.60V	+ 2.50V	
K	+ 2.50V	+ 1.60V	
L	+ 1.50V	+ 1.50V	
M	NA	NA	+ 39V
N	NA	NA	+ 6V
P	+ 34.5V	+ 11.6V	
R	+ 11.6V	+ 34.5V	
S	NA	NA	+ 6V

Test points G and H indicate that R212 is adjusted properly, when 2.7 volts is measured across them.

Delay wave form:

The amount of delay by the delay line is noted in figure 15. This was done by setting the input switch to DC and connecting a 1 volt p-p square wave signal to the input. The VOLTS/DIV switch is placed on the 1V/DIV. range. Signals are observed at test point J and test point P, on a dual trace scope.

Power Supply Test Points.

For correct readings at these test points the preregulator should be adjusted so that positive 135 is read at test point A on the power supply. Also the minus 800 supply should be adjusted for proper regulation. (See Calibration Procedure Section VI.)

TEST POINT: A + 135V

TEST POINT: B - 33V DC Level
See Fig.16 for wave form.

TEST POINT: C - 1.15V DC Level
See Fig. 17 for wave form.

***** NOTE TEST POINTS D AND E ARE MEASURED IN REFERENCE TO THE POSITIVE SIDE OF CAPACITOR C102.

TEST POINT: D - .5V

TEST POINT: E + 15V

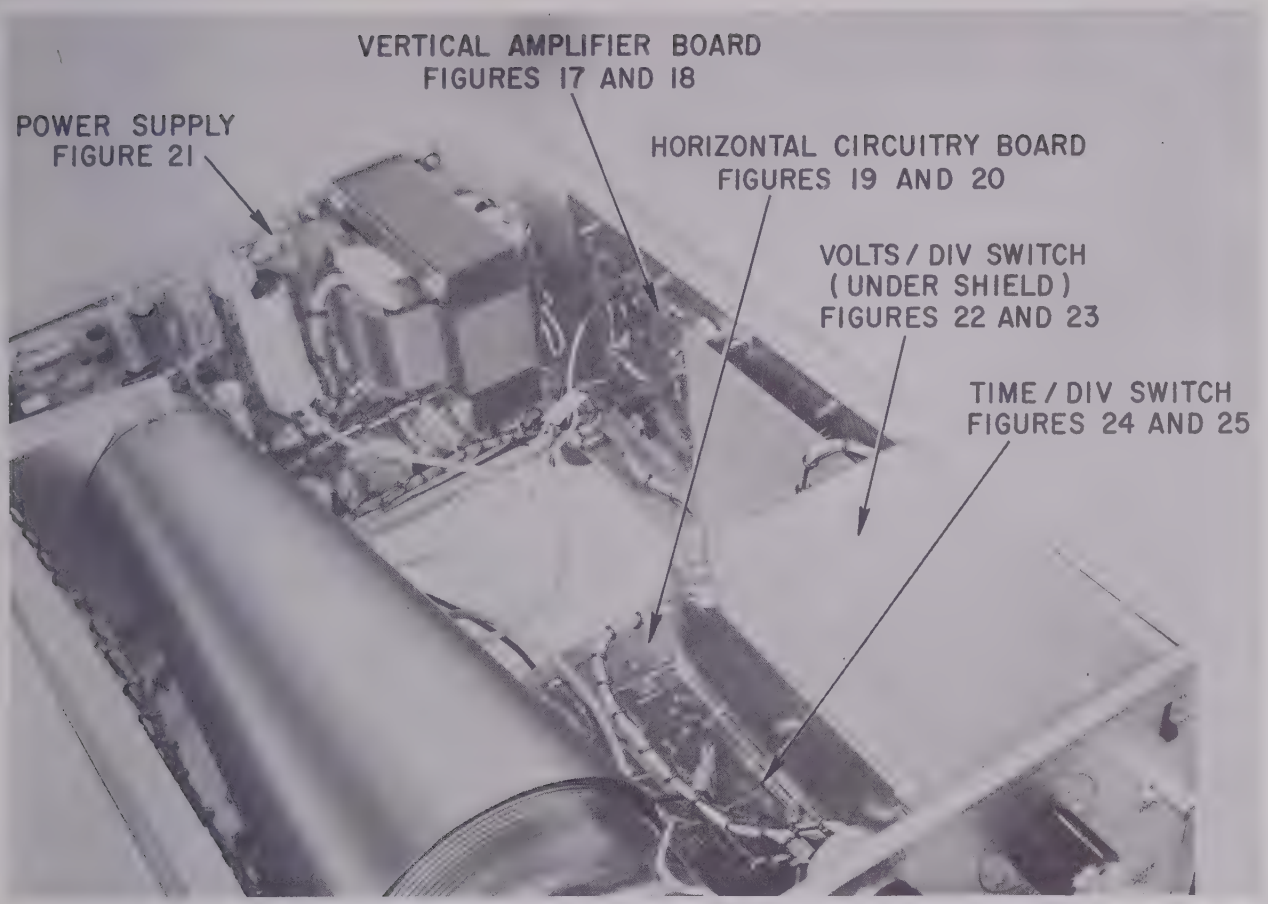


Figure 16. Location of Subassemblies Which Show Components

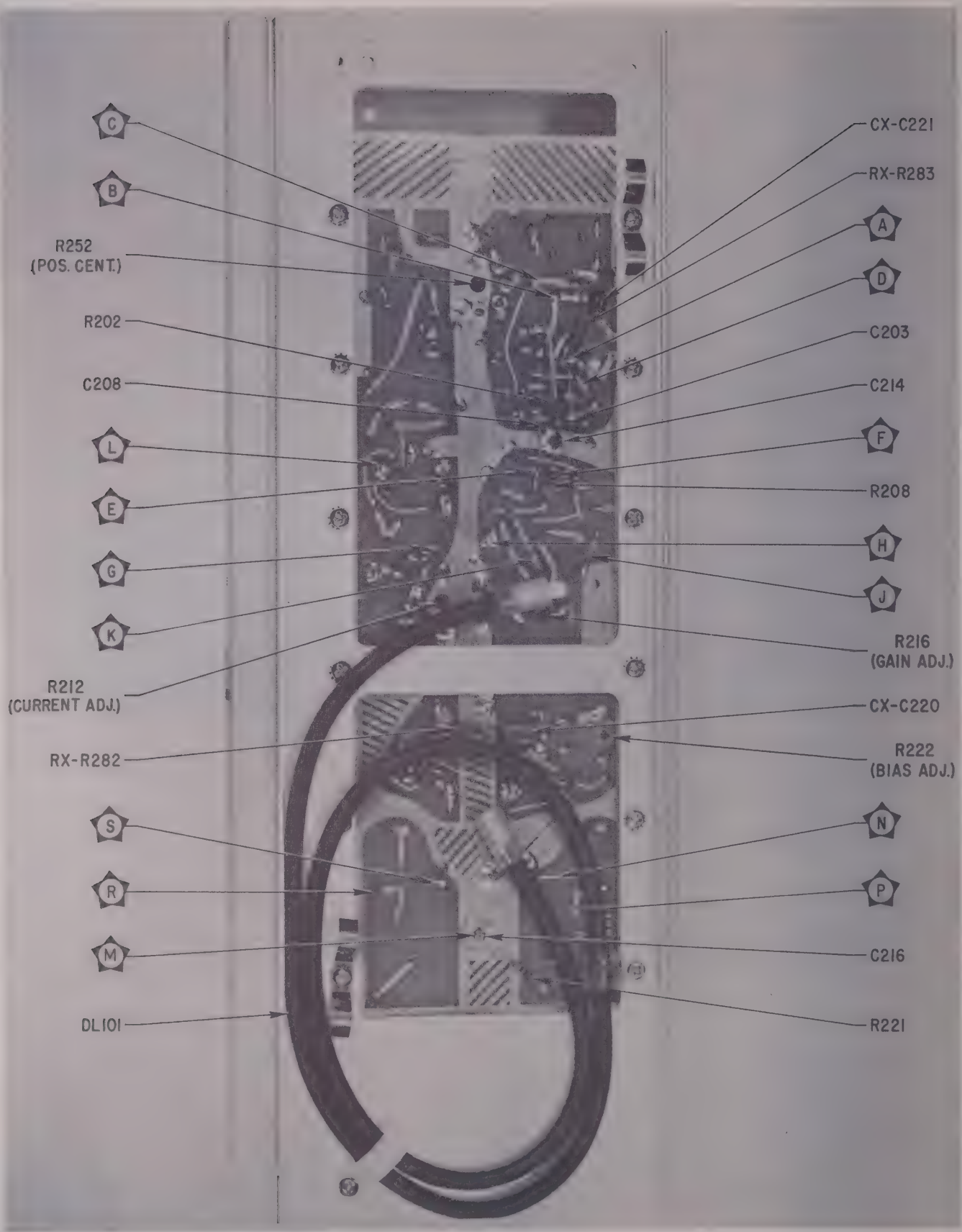


Figure 17. Vertical Amplifier Board (shown from outside)

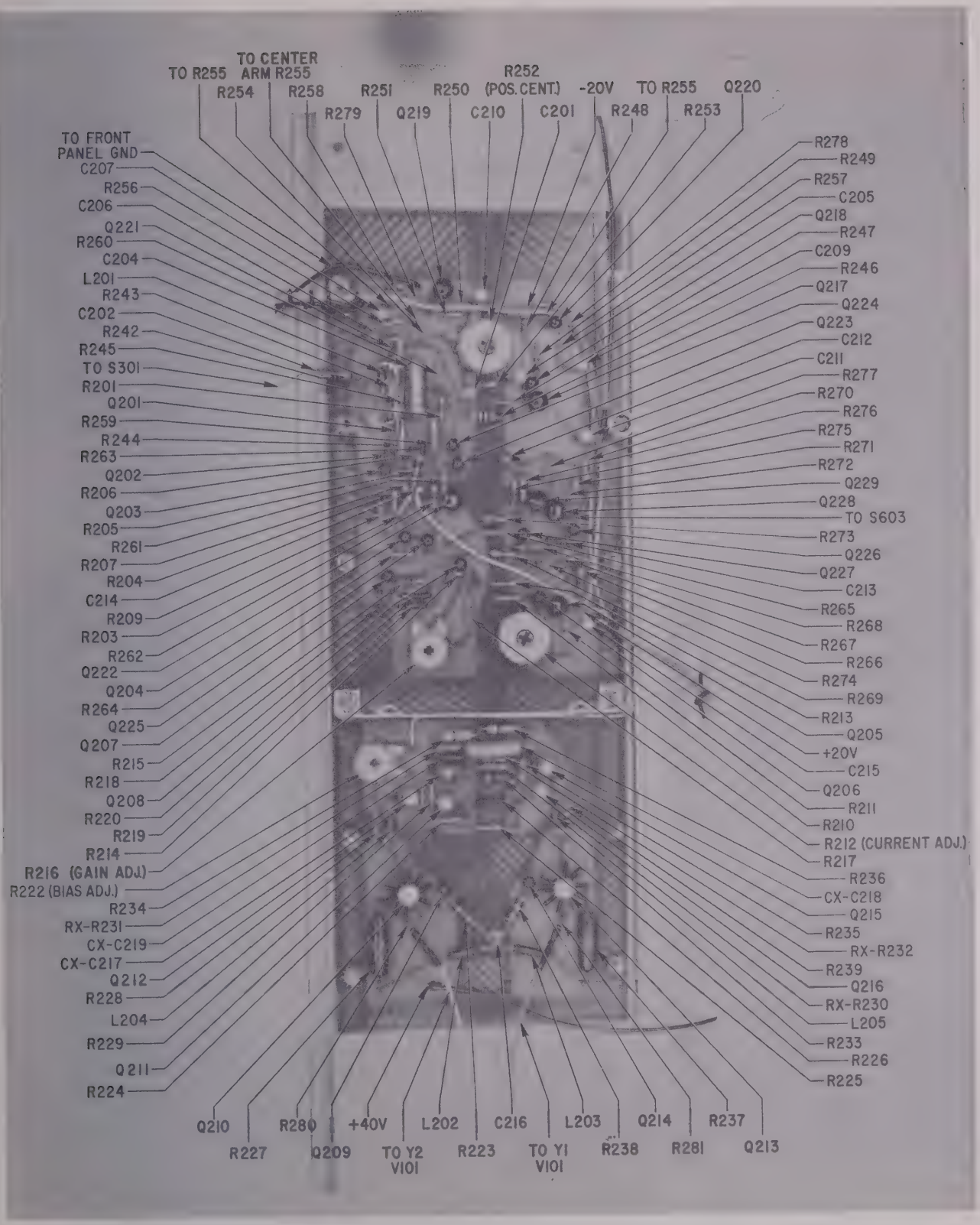


Figure 18. Vertical Amplifier Board (shown from inside)

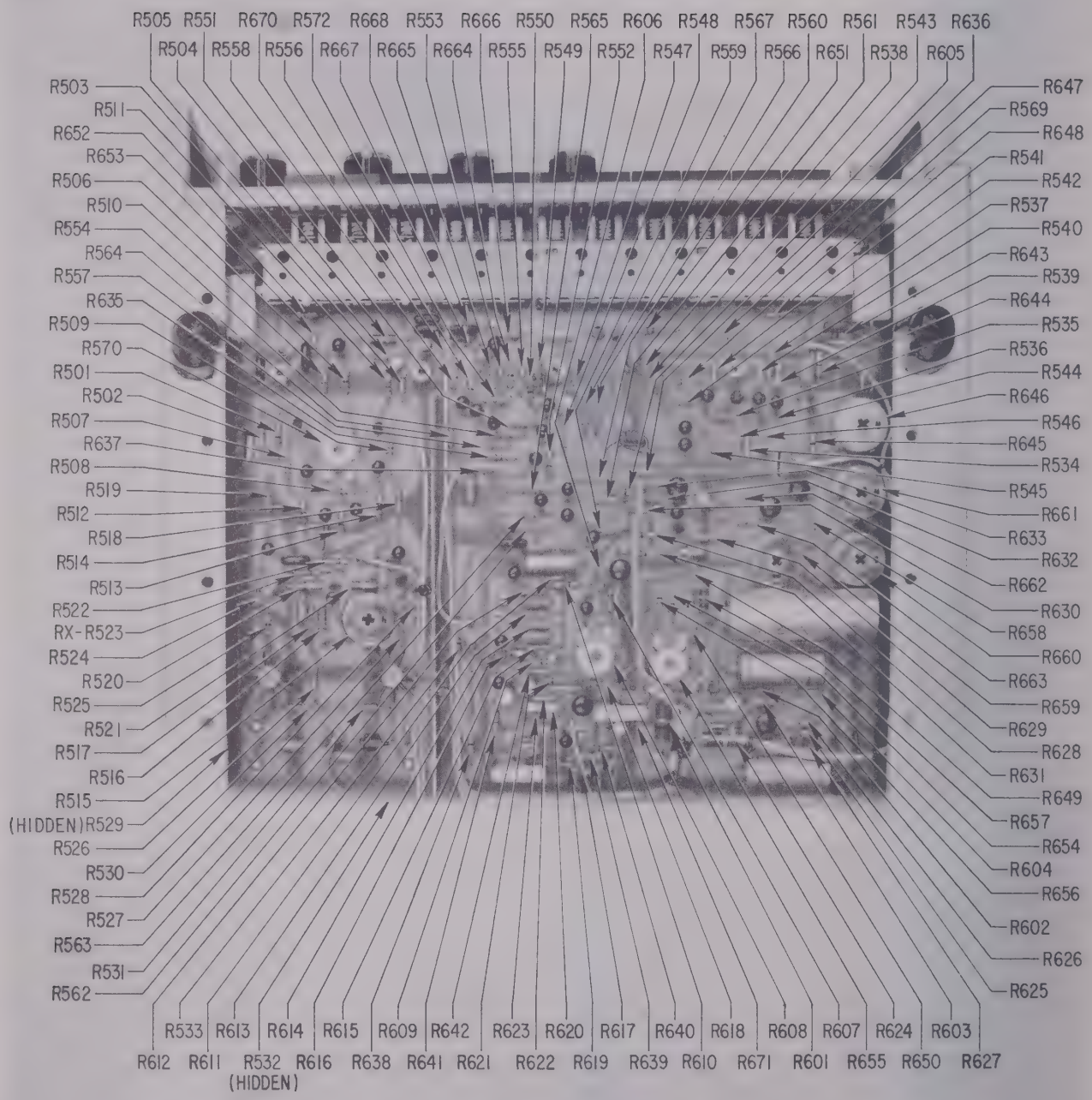


Figure 19. Horizontal Circuitry Board (resistors)

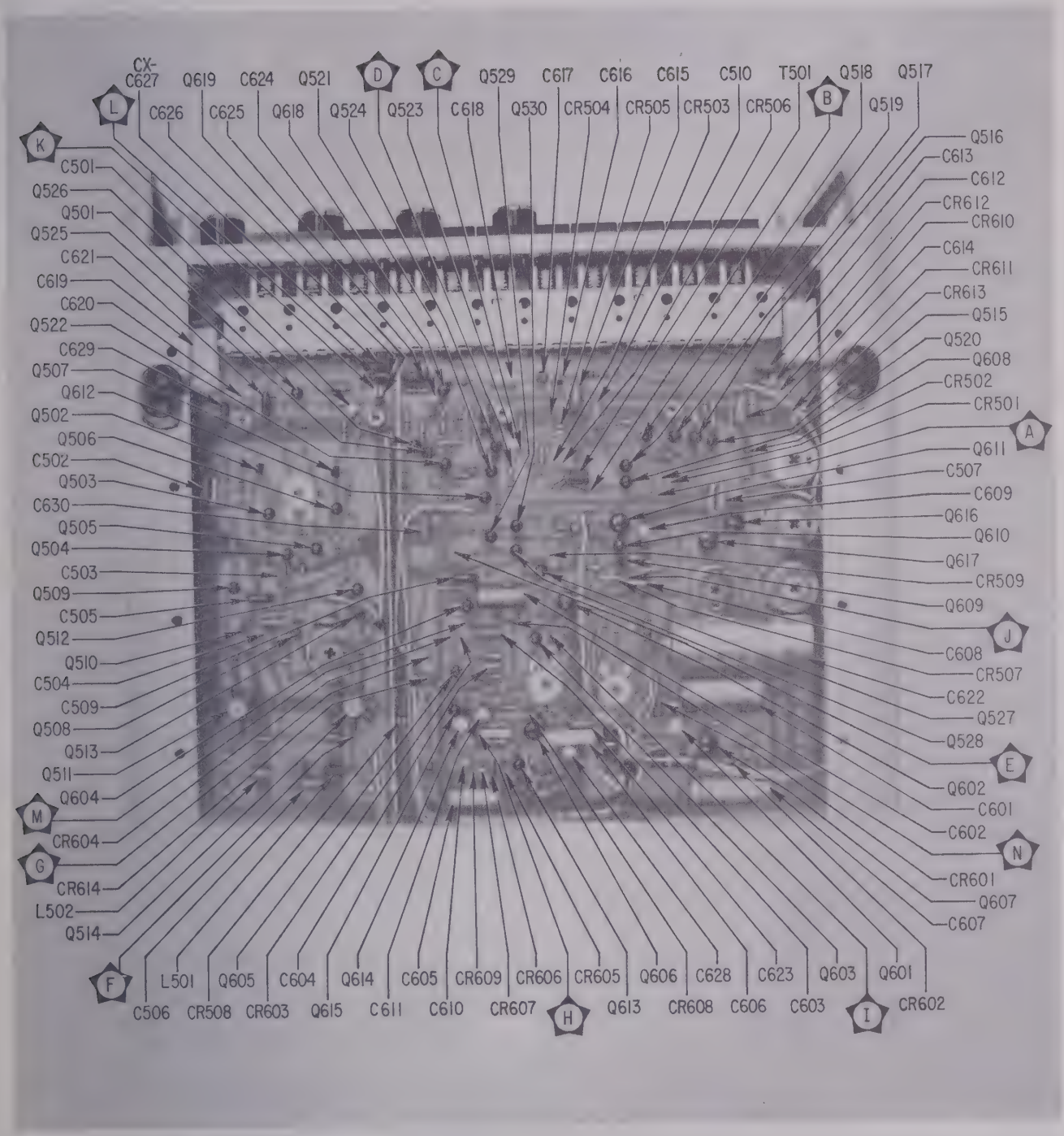


Figure 20. Horizontal Circuitry Board (other components)

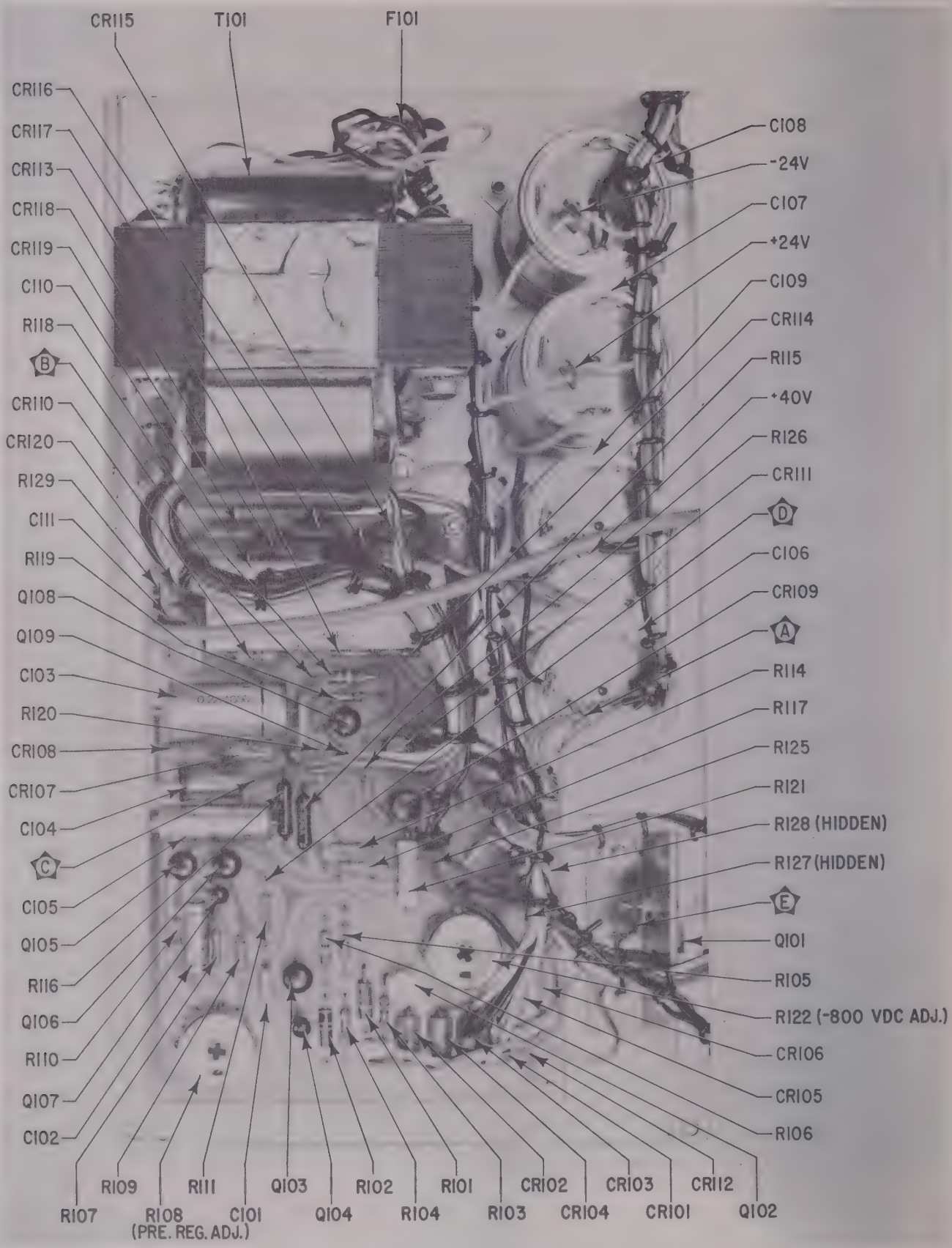


Figure 21. Power Supply

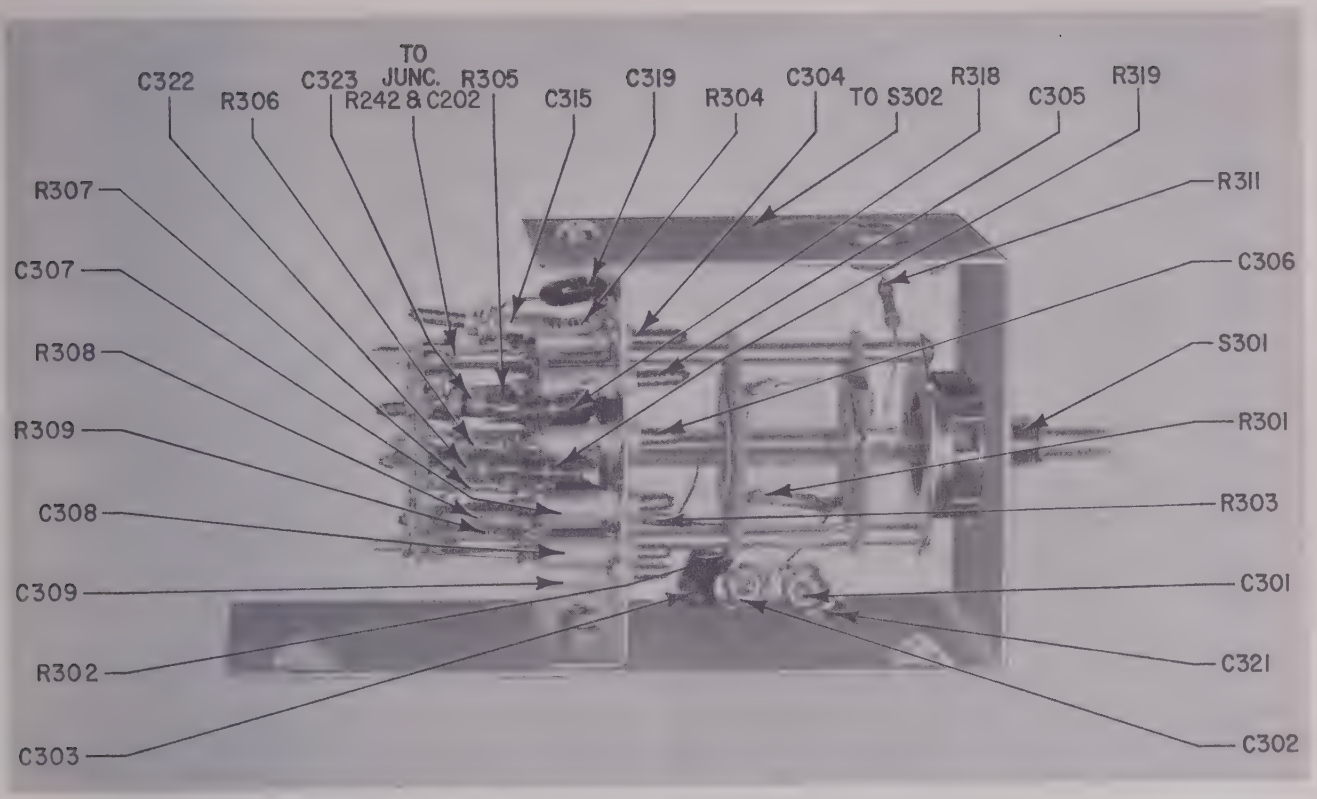


Figure 22. VOLTS/DIVISION Switch (viewed from top)

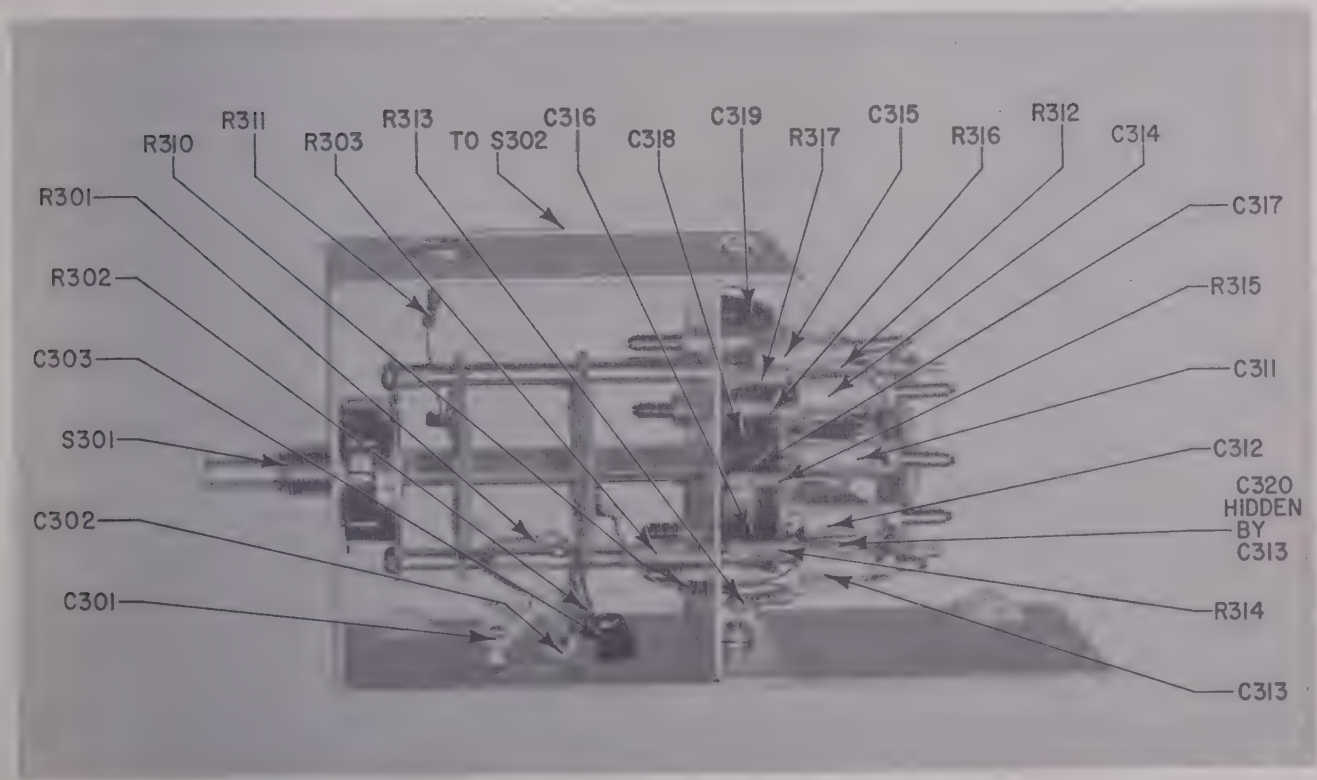


Figure 23. VOLTS/DIVISION Switch (viewed from bottom)

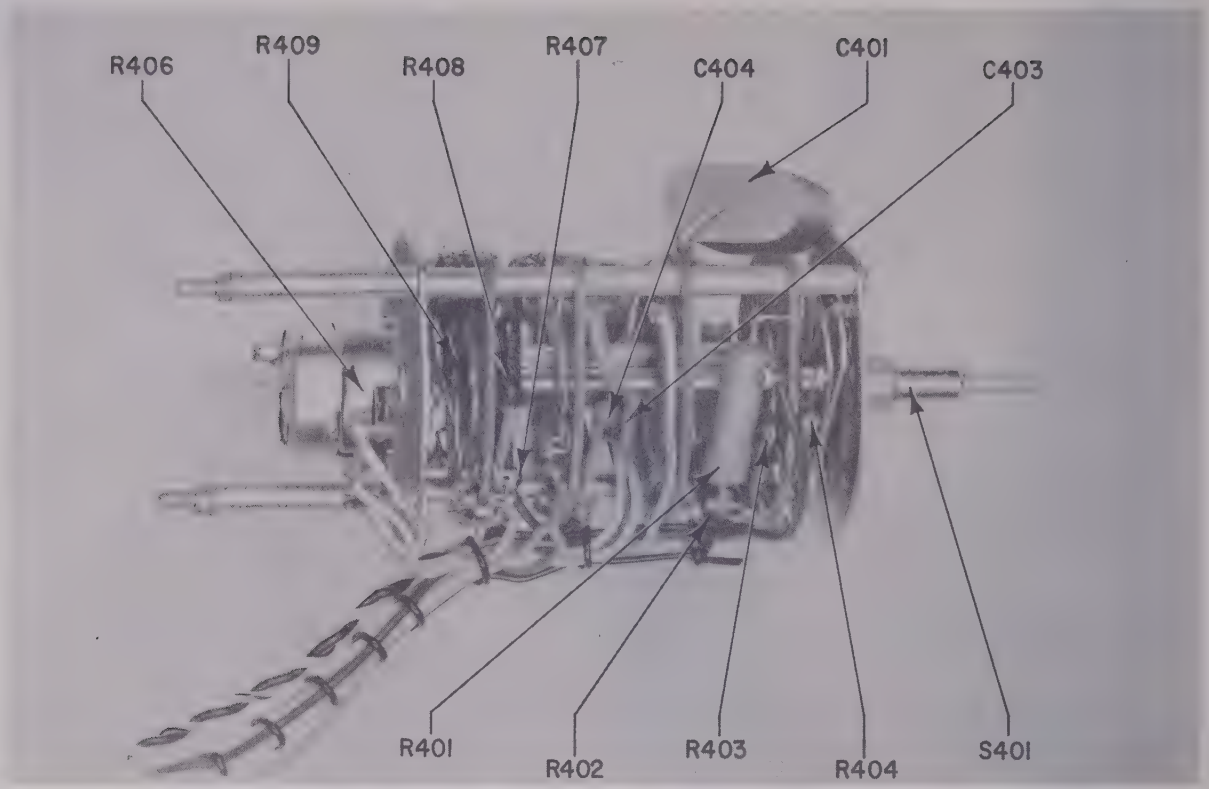


Figure 24. TIME/DIVISION Switch (viewed from top)

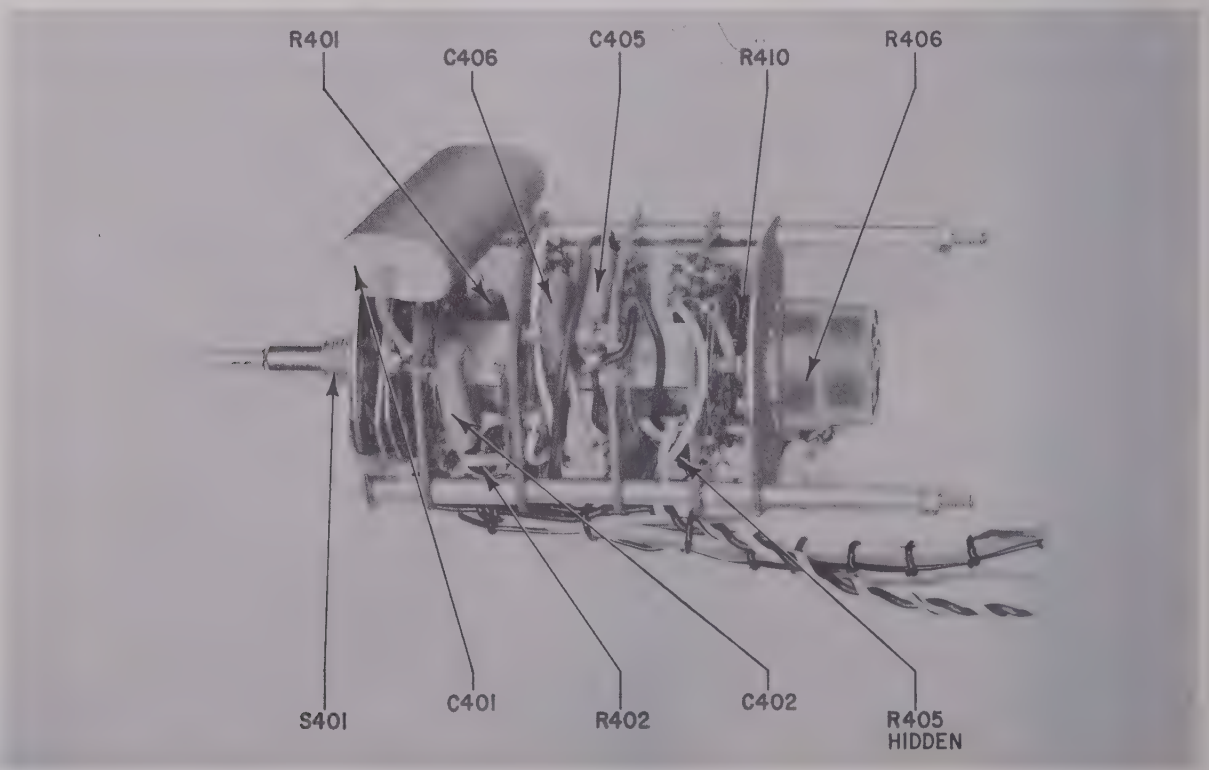


Figure 25. TIME/DIVISION Switch (viewed from bottom)

SECTION VI
CALIBRATION PROCEDURE

The Model CRO5000 is a stable instrument which will provide many hours of trouble-free operation. However, in order to insure the accuracy of indications it is suggested that the calibration be checked periodically. This will not only insure the accuracy of measurements, but will also serve as a form of preventive maintenance, in that it will help detect developing troubles in the circuitry.

It is also necessary to recalibrate after the replacement of components, in a particular section. If it is necessary to recalibrate the power supplies, the calibration of the unit should then be checked.

The suggested equipment for calibration is as follows:

DC Voltmeter: DP-110 and DMS-3200 combination. Required 1% or better accuracy with 100mV full scale capability for DC readings.

Test Scope: CRO5000 recommended. Require calibrated vertical and horizontal deflection.

Time Mark Generator: Hickok Model 1817 or equivalent.

AC Voltmeter: DP-130. Required 1% or better accuracy on a 21.2mV rms sinewave signal.

Low Frequency Squarewave Generator & Sinewave Oscillator: Require up to 5V squarewave output. Output frequency range 20Hz to 100kHz for square wave and up to 1MHz for sine wave. No overshoot or ringing on square wave; low distortion on sinewave.

Capacity Meter: DP-200. Required to measure 30pf capacity accurately.

High Frequency Squarewave Generator: Tektronix Type 107 or equivalent.

For the following procedures the input line should be set to 117V.

1. Calibration of power supplies.

   a. Connect the voltmeter across the + 135V supply at C106. Test point A.

   b. Adjust R108, the Pre-reg. Adj., for a reading of exactly 135 volts.

   c. Connect the probe of the test probe to the junction of R118 and R119, Test Point B.

   d. Set the vertical sensitivity of the test scope to 50V/DIV and locate the ground reference line at the topmost graticule line.

   e. Adjust R122, and -800V adj., so that the ripple observed, with the INTENSITY control in the maximum clockwise position, is centered between the ground reference and -135V without clipping at either end of the waveform.

2. Raster shape adjustment.

   a. Connect a sine wave oscillator to the vertical input and adjust the amplitude for a six division deflection and the frequency to approximately 1MHz.

   b. Connect another sinewave oscillator to the HORIZONTAL DISPLAY INPUT and depress the IN = DC button.

      (1) Adjust the amplitude of the oscillator for a full scale deflection in the horizontal direction.

      (2) Adjust the output frequency for approximately 1kHz.

   c. Adjust R655, the Raster Shape Adj., for the optimum raster shape, with a minimum of bowing on the extremes of deflection.

3. Adjustment of calibrator output.

   a. Connect the voltmeter to the calibrator output jack (CAL .6V P-P).

   b. Use a clip lead to form a short circuit between the collector of Q604 (Test Point M) and the junction of R610 and R612 (Test Point W), and note the reading of the voltmeter. The approximate reading should be 10mV.

   c. Move the jumper from Test Point N (junction of R610 and R602) to ground.

   d. Adjust R608 (CAL Voltage Adj.) for a reading of 600 millivolts plus the voltage measured in step b. above.

4. Horizontal amplifier calibration.

   Set the front panel controls as follows:

VERTICAL POSITION	Trace centered
VERTICAL INPUT	DC
VOLTS/DIV	.5V/DIV
HORIZONTAL DISPLAY	X-AXIS button depressed

   a. Rotate the HORIZONTAL POSITION control to its maximum counterclockwise position. Measure the voltage at the collector of Q511, Test Point F. Adjust R515 (Current Adj.) until a reading of approximately 2.0 volts is obtained.

   b. Apply a 2.5V peak to peak 1kHz squarewave to the horizontal input and a 1kHz sinewave to the VERT INPUT. Center trace horizontally. Adjust the sinewave output for full screen deflection.

c. Adjust C620 for minimum over or under compensation of the squarewave. A properly adjusted squarewave will result in two straight lines perpendicular to the horizontal axis.

5. Calibration of horizontal gain.

a. Apply exactly 2.0V peak to peak signal to the horizontal input. Deflection should be 10 divisions ± 2 minor divisions.

b. If it is necessary to recalibrate the horizontal amplifier, remove R523 from the circuit and connect the decade resistance box from the emitter of Q509 to the emitter of Q512 and set the AC-DC-GND selector switch to GND.

c. Adjust the resistance box to obtain 10 divisions of deflection ±2 small divisions.

d. Insert the value of resistance determined in step 3 at RX-R523 in the circuit. Recheck horizontal gain by applying a 2.0V peak to peak signal and obtaining a 10 division deflection ±2 small divisions.

6. Adjustment of external trigger source follower.

a. Connect the DC voltmeter to the junction of the source of Q608 and R645.

b. Adjust R646 for a reading of zero volts ±10mV.

7. Adjustment of sweep timing.

NOTE: As an aid to calibration, R570 (Bal. Adj.) should be adjusted so that the undeflected spot on the beginning of trace falls exactly on the 5th division with the Position control in the extreme clockwise direction. When adjusting the sweep ranges the 6th marker should be aligned on the 5th division before adjustment. When adjusting the sweep it will be noted that the 6th marker will move little from the 5th division and the necessity of readjusting the Position control will be greatly reduced.

a. Connect 1817 Time Mark Generator to VERT/INPUT. Set output for four major divisions. Timing should be measured between first and ninth graticules lines with ±1 minor division. Use the following table to adjust timing:

TABLE III. TIME BASE CALIBRATION

Time/div	Time Mark Generator	Timing Adjustment
50 μs	50 μs	R660
.1ms	100 μs	R660
.2ms	200 s	R660
5 μs	5 μs	R661
10 μs	10 μs	R661
20 μs	20 μs	R661
50ms	50ms	R659
.1 sec	100ms	R659
.2 sec	200ms	R659

8. Adjust horizontal positioning range.

a. Depress the X-AXIS button and position the trace to the center of screen.

b. Connect a 1 volt p-p SINEWAVE to the Horizontal Input.

c. Adjust the HORIZONTAL POSITION control to its maximum clockwise extreme and adjust R570 (Bal. Adj.) until only 1/2 of one division of trace remains on screen on the right-hand side of screen.

Calibration of vertical amplifier.

a. Set the controls of the scope under test as follows:

VERTICAL POSITION	Trace centered
AC-DC-GND Selector	GND
VOLTS/DIV Selector	10mV/DIV
AUTO button	Depressed
+ button	Depressed
DC button	Depressed
INT button	Depressed
TIME/DIV Selector	1ms/DIV
HORIZONTAL POSITION	Full screen trace
ASTIG.	Sharp Trace
FOCUS	Sharp Trace
TRIGGER LEVEL	Triggered sweep

b. Set the VERTICAL POSITION control to its mechanical center and adjust R252 (Pos. Cent.) to bring the trace to the center graticule line.

c. Adjust R212 (Current Adj.) for a voltage reading of 2.70V across R213, Test Points G and H.

d. Adjust R222 (Bias Adj.) to the center of its rotation.

e. Turn the VERTICAL POSITION control to its maximum counterclockwise position and measure the voltages at the junction of L202 and L203 and also at the base of Q210.

f. Check the voltage at the collector of Q213. The voltage reading should be at least 2V less than the reading taken at the junction of L202 and L203.

g. Check the voltage at the collector of Q210. The voltage reading should be at least 2V greater than the reading at the base of Q210.

h. Rotate the positioning control fully clockwise and measure the voltage at the base of Q213. Measure the voltage at the collector of Q213. The voltage reading should be at least 2V greater than the reading at the base of Q213.

i. Measure the voltage at the collector of Q210. The reading should be at least 2V less than the reading at the junction of L202 and L203.

j. Set the AC-DC-GND switch to DC. Apply a 1kHz sinewave to the VERT/INPUT. Adjust the sinewave amplitude for the divisions of DEFLECTION. Rotate the VERTICAL POSITION control between its extremes and check to see that the trace goes off screen in both directions. Adjust R222 (Bias Adj.) if trace will not go off screen in both directions.

k. Connect the AC voltmeter to the output of the sinewave oscillator. The oscillator should already by connected to the VERT INPUT. Adjust the oscillator output until the AC voltmeter reads exactly 21.2mV. Adjust R216 (Gain Adj.) for 6 divisions of deflection.

9. Compensation of vertical attenuator.

a. Set the front panel controls as follows:

AC-DC-GND	DC
VOLTS/DIV	10mV/DIV
VERTICAL POSITION	Centered
AUTO button	Depressed
+ button	Depressed
DC button	Depressed
INT button	Depressed
HORIZONTAL POSITION	Full screen deflection

b. Connect the DP200 capacity plug-in to the VERT INPUT connector. Adjust C304 for a reading of 30pF on the DP200 meter.

c. Connect the squarewave generator to the VERT INPUT connector. Set the generator for 5kHz and adjust the output for full screen deflection. Check the squarewave for proper compensation, i.e., no over or under compensation and no tilt.

d. Set the VOLTS/DIV selector to the 20mV/div range. Adjust the generator output for a full screen deflection. Adjust C313 for a properly compensated squarewave.

e. Repeat step c for the 50mV/DIV range. Adjust C312 for a properly compensated squarewave.

f. Repeat step c for the .1 VOLT/DIV range. Adjust C311 for a properly compensated squarewave.

g. Repeat step c for the .2V/DIV range. Adjust C314 for a properly compensated squarewave.

h. Repeat step c for the .5V/DIV range. Adjust C315 for a properly compensated squarewave.

i. Repeat step c for the 1V/DIV range. Adjust C302 for a properly compensated squarewave.

j. Connect a 10:1 probe to the VERT INPUT and set the VOLTS/DIV selector to the 10mV range. Apply a .6V p-p squarewave to the probe and adjust the probe for a properly compensated squarewave.

k. Change the VOLTS/DIV selector to the 20mV range and increase the squarewave generator output for a full scale deflection. Adjust C305 for a properly compensated squarewave.

l. Repeat step k for the 50mV/DIV range. Adjust C306.

m. Repeat step k for the .1V DIV range. Adjust C307.

n. Repeat step k for the .2V/DIV range. Adjust C308.

o. Repeat step k for the .5V/DIV range. Adjust C309.

p. Repeat step k for the 1V/DIV range. Adjust C301.

10. Vertical amplifier frequency response calibration.

Visually verify that the following components are on the amplifier circuit board and locate them:

RX-R230	-	CX-C217
RX-R231	-	CX-C218
RX-R232	-	CX-C219
RX-R282	-	CX-C220
RX-R283	-	CX-C221

Do not change the value of the above components unless the unit is out of tolerance. This can be determined by the following procedure:

a. Set the front panel controls as follows:

VOLTS/DIV Selector	10mV/div
AC-DC-GND Selector	DC
TRIGGER MODE	DC
TRIGGER SOURCE	INT
TRIGGER SLOPE	+
TIME/DIV	Comfortable viewing rate

b. Connect the low frequency squarewave generator output to the Vertical Input connector. Set the generator for 20Hz and adjust the output for full scale deflection. If the leading edge of the squarewave has overshoot or rounding in excess of 1%, change the value of RX-R282. Decreasing the value of RX-R282 will peak the squarewave.

c. Repeat step b with the generator set to 100Hz. If necessary, change the value of RX-R231 to compensate the squarewave.

d. Repeat step b with the generator set to 1kHz. If necessary, change the value of RX-R230.

e. Repeat step b with the generator set to 100kHz. If necessary, change the value of RX-R283.

f. Connect the high frequency squarewave generator to the VERT INPUT with a 10:1 attenuator at the generator and a 50 ohm termination at the input connector. Set output frequency to 1MHz and amplitude for full scale deflection. If necessary, change the value of RX-R232 to compensate the squarewave.

SECTION VII
PARTS LIST

Reference designations have been assigned to identify all parts used in this instrument. An asterisk designates a part which should be replaced by authorized Hickok repair stations or factories. It is therefore recommended that the entire instrument be returned for repair if trouble exists with such a part.

In ordering parts, refer to the current parts price list for this instrument. Prices are subject to change without notice, and the minimum billing charge is $3.50.

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
C101	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .047 μF, 10%, 200V	3092-209
C102	CAPACITOR, FIXED, ELECTROLYTIC: 40 μF, 16 V	3085-345
C103	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .22 μF, 10%, 1000V	3103-66
C104	CAPACITOR, FIXED, POLYESTER FILM: .01 μF, 10%, 1000 V	3103-57
C105	CAPACITOR, FIXED, ELECTROLYTIC: 15 μF, 150 V	3085-354
C106	CAPACITOR, FIXED, ELECTROLYTIC: 200 μF, 150 V, common negative	3085-346
C107	CAPACITOR, FIXED, ELECTROLYTIC: 3000 μF, 25 V, common negative	3085-349
C108	CAPACITOR, FIXED, ELECTROLYTIC: 3000 μF, 25 V, common positive	3085-348
C109	CAPACITOR, FIXED, ELECTROLYTIC: 1200 μF, 50 V, common negative	3085-347
C110	CAPACITOR, FIXED: .1 μF, 20%, 3000 V	3103-67
C111	CAPACITOR, FIXED, DISC CERAMIC: .005 μF, 20%, 3000 V	3110-281
C201	CAPACITOR, FIXED, CERAMIC: 2200 pF, +50 - 20%, 500 V	3111-524
C202	CAPACITOR, FIXED, CERAMIC: feed through, 1000 pF, +100 -0%, 500 V	3110-284
C203	CAPACITOR, FIXED, CERAMIC: 2.2 pF ±.25 pF, temp. coeff. NPO ±120, 500 V	3110-282
C204	CAPACITOR, FIXED, ELECTROLYTIC: 50 μF, 25 V	3085-300
C205	CAPACITOR, FIXED, CERAMIC: 4700 pF, +50 -20%, 500 V	3111-526
C206	CAPACITOR, FIXED, CERAMIC: 1000 pF, +50 -20%, 500 V	3111-522
C207	CAPACITOR, FIXED, ELECTROLYTIC: tantalum, 4.7μF, 25 V	3085-343
C208	Same as C203	
C209, C210	Same as C205	
C211	Same as C207	
C212	Same as C206	
C213	CAPACITOR, FIXED, DIPPED MICA: 27 pF, 5%, 500 V	3096-511
C214	CAPACITOR, FIXED, 1000 pF, feed through	3110-279
C215	Same as C207	
C216	Same as C214	
C217 thru C221	CAPACITOR, FIXED: calibration, values determined in production	
C301, C302	CAPACITOR, VARIABLE: trimmer, 0.9 - 9 pF	3115-73
C303	CAPACITOR, FIXED, DIPPED MICA: 470 pF, 5%, 500 V	3096-541
C304 thru C309	Same as C301	
C310	CAPACITOR, FIXED, POLYESTER FILM: .1 μF, 10%, 630 V	3103-71
C311 thru C315	Same as C301	
C316	CAPACITOR, FIXED, DIPPED MICA: 10 pF, 10%, 500 V	3096-505
C317	CAPACITOR, FIXED, DIPPED MICA: 22 pF, 10%, 500 V	3096-509
C318	CAPACITOR, FIXED, DIPPED MICA: 56 pF, 5%, 500 V	3096-519
C319	CAPACITOR, FIXED, DIPPED MICA: 180 pF, 5%, 500 V	3096-531
C320	CAPACITOR, FIXED, CERAMIC: 5 pF ±.25 pF, temp. coeff. NPO ±120, 500 V	3110-283
C321	CAPACITOR, FIXED, DIPPED MICA: 5 pF, 10%, 500 V	3096-501
C322	CAPACITOR, FIXED, COMPOSITION: .22 μF, 10%, 500 V	3116-8
C323	CAPACITOR, FIXED, COMPOSITION: .33 pF, 10%, 500 V	3116-9
C401, C402	CAPACITOR: pair, measured and matched within 2%	3121-32
C403	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .022 μF, 10%, 200V	3092-205
C404	Same as C206	
C405	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .47 μF, 10%, 200 V	3092-221
C406	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .22 μF, 10%, 200 V	3092-217
C501	Same as C207	
C502 thru C504	CAPACITOR, FIXED, MFTALLIZED POLYESTER FILM: .1 μF, 10%, 200 V	3092-213
C505	CAPACITOR, FIXED, DIPPED MICA: 220 pF, 5%, 500 V	3096-533
C506 thru C508	Same as C502	
C509	Same as C505	
C510	Same as C502	
C511	Same as C505	
C601	CAPACITOR, FIXED, ELECTROLYTIC: 250 μF, 25 V	3085-324
C602	Same as C204	
C603, C604	Same as C403	
C605, C606	Same as C405	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
C607	Same as C601	
C608	Same as C403	
C609	Same as C205	
C610	Same as C201	
C611	CAPACITOR, FIXED, CERAMIC: 470 pF, 20%, 500 V	3111-520
C612	Same as C213	
C613	Same as C310	
C614, C615	Same as C502	
C616, C617	CAPACITOR, FIXED, ELECTROLYTIC: tantalum, 10μF, 10 V	3085-344
C618	Same as C101	
C619	Same as C310	
C620	Same as C301	
C621	Same as C318	
C622	CAPACITOR, FIXED, ELECTROLYTIC: 100 μF, 150 V	3085-353
C623	Same as C502	
C624	Same as C201	
C625	CAPACITOR, FIXED, CERAMIC: 100 pF, 20%, 500 V	3111-516
C626	CAPACITOR, FIXED, DIPPED MICA: 330 pF, 5%, 500 V	3096-537
C627	CAPACITOR, FIXED: calibration, value determined in production	
C628	Same as C207	
C629	CAPACITOR, FIXED, DIPPED MICA: 15 pF, 10%, 500 V	3095-267
CR101 thru CR104	SEMICONDUCTOR DEVICE: BY127 rectifier	3870-233
CR105, CR106	SEMICONDUCTOR DEVICE: diode 1N914	3870-175
CR107, CR108	Same as CR101	
CR109	SEMICONDUCTOR DEVICE: silicon integrated bridge rectifier	3870-234
CR110	Same as CR101	
CR111	SEMICONDUCTOR DEVICE: diode bridge	3870-227
CR112	SEMICONDUCTOR DEVICE: 1N720A, 18 V ±5%	3870-159
CR113, CR114	SEMICONDUCTOR DEVICE: diode 1N2069	3870-62
CR115 thru CR120	Same as CR101	
CR501 thru CR509	Same as CR105	
CR601, CR602	SEMICONDUCTOR DEVICE: diode 2.4 V, 1 watt, 20%	3870-245
CR603, CR604	Same as CR105	
CR605, CR606	Same as CR112	
CR607	Same as CR105	
CR308	Not used	
CR609-CR614	Same as CR105	
DL101	DELAY LINE ASSEMBLY	4115-10
DS101	LAMP: pilot, clear red, with resistor	12270-60
F101	FUSE: 1 amp, tubular	6900-1
J101	CONNECTOR: CRT post accelerator, with 18 in. lead	3475-242
J301	CONNECTOR, RECEPTACLE: single contact, RF coaxial type, UG-657/U	3475-144
J601	JACK: pin, red nylon body	10300-55
J602, J603	Same as J301	
L201	COIL, RF: .24 μH	3250-501
L202, L203	COIL, RF: 1.5 μH	3250-508
L204, L205	Same as L201	
L501, L502	COIL, RF: 15.00 μH	3250-522
P101	CORD AND PLUG ASSEMBLY: 3 wire	3675-34
Q101	TRANSISTOR: 2N5297	20861-216
Q102	TRANSISTOR: 2N2102	20861-165
Q103	TRANSISTOR: 2N4889	20861-204
Q104	SEMICONDUCTOR, ZENER DIODE	3870-242
Q105, Q106	TRANSISTOR: 2N3566	20861-122
Q107	Same as Q104	
Q108	Same as Q103	
Q109	TRANSISTOR: 2N5138	20861-221
Q201	Part of matched pair 20861-214 (with Q221)	20861-214
Q202	TRANSISTOR: 2N3640	20861-72
Q203	TRANSISTOR: 2N4258	20861-197
Q204	TRANSISTOR: 2N5126	20861-213
Q205	SEMICONDUCTOR, ZENER DIODE	3870-240

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
Q206	TRANSISTOR: 2N5139	20861-181
Q207, Q208	Same as Q203	
Q209	Same as Q104	
Q210	TRANSISTOR: 2N3866	20861-226
Q211	TRANSISTOR: 2N5179	20861-195
Q212	TRANSISTOR: 2N3012	20861-209
Q213	Same as Q210	
Q214	Same as Q104	
Q215	Same as Q212	
Q216	Same as Q211	
Q217	Same as Q105	
Q218	SEMICONDUCTOR, ZENER DIODE	3870-244
Q219	Same as Q205	
Q220	Same as Q104	
Q221	Part of matched pair 20861-214 (with Q201)	20861-214
Q222	SEMICONDUCTOR, ZENER DIODE	3870-238
Q223	Same as Q203	
Q224	Same as Q202	
Q225	Same as Q204	
Q226, Q227	Same as Q202	
Q228, Q229	Same as Q105	
Q501	Same as Q206	
Q502	Part of matched pair 20861-223 (with Q507)	20861-223
Q503	TRANSISTOR: 2N5130	20861-171
Q504, Q505	Same as Q104	
Q506	Same as Q503	
Q507	Part of matched pair 20861-223 (with Q502)	20861-223
Q508	TRANSISTOR: 2N5306	20861-159
Q509	Same as Q503	
Q510	TRANSISTOR: 2N3906	20861-139
Q511	TRANSISTOR: 2N2102 selected	20861-229
Q512	Same as Q503	
Q513	Same as Q510	
Q514	Same as Q511	
Q515 thru Q518	Same as Q503	
Q519, Q520	Same as Q203	
Q521, Q522	Same as Q104	
Q523	Same as Q211	
Q524 thru Q526	Same as Q503	
Q527	Same as Q105	
Q528	Same as Q202	
Q529	Same as Q104	
Q530	Same as Q202	
Q601	TRANSISTOR: 2N5183	20861-227
Q602	Same as Q205	
Q603 thru Q605	Same as Q503	
Q606	Same as Q103	
Q607	TRANSISTOR: 2N5040	20861-224
Q608	TRANSISTOR: MPF104 field effect	20861-132
Q609	TRANSISTOR: 2N4870 unijunction	20861-144
Q610	Same as Q503	
Q611	Same as Q105	
Q612, Q613	Same as Q204	
Q614	TRANSISTOR: 2N5184	20861-200
Q615	Same as Q206	
Q616	Same as Q205	
Q617	TRANSISTOR: 2N3644	20861-107
Q618	Same as Q204	
Q619	TRANSISTOR: MPS918	20861-202
R101	RESISTOR, FIXED, COMPOSITION: 1200 ohms, 10%, 1/2 watt	18412-122
R102	RESISTOR, FIXED, COMPOSITION: 1.0 ohm, 10%, 1/2 watt	18525-815
R103	RESISTOR, FIXED, DEPOSITED CARBON: 100 ohms, 5%, 1/4 watt	18470-101
R104, R105	RESISTOR, FIXED, DEPOSITED CARBON: 470 ohms, 5%, 1/4 watt	18470-471

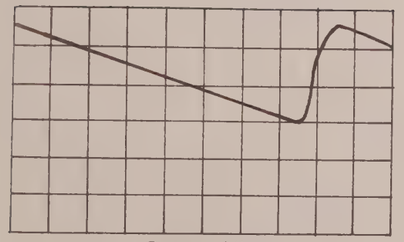
REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R106	RESISTOR, FIXED, DEPOSITED CARBON: 10K ohms, 5%, 1/4 watt	18470-103
R107	RESISTOR, FIXED, DEPOSITED CARBON: 3300 ohms, 5%, 1/4 watt	18470-332
R108	RESISTOR, VARIABLE: wire wound, 1K ohms, 20%, 2 watt, printed circuit mtg	16925-576
R109	RESISTOR, FIXED, DEPOSITED CARBON: 1800 ohms, 5%, 1/4 watt	18470-182
R110	Same as R104	
R111	RESISTOR, FIXED, DEPOSITED CARBON: 4700 ohms, 5%, 1/4 watt	18470-472
R112	RESISTOR, FIXED, DEPOSITED CARBON: 47K ohms, 5%, 1/4 watt	18470-473
R113	RESISTOR, VARIABLE: composition, 100K ohms, 10%, 1/2 watt	40300-104
R114	RESISTOR, FIXED, DEPOSITED CARBON: 2700 ohms, 5%, 1/4 watt	18470-272
R115, R116	RESISTOR, FIXED. METAL FILM: 806K ohms, 1%, 1/2 watt	18526-24
R117	Not used	
R118	RESISTOR, FIXED, COMPOSITION: 15K ohms, 10%, 1/2 watt	18413-152
R119	RESISTOR, FIXED, DEPOSITED CARBON: 1000 ohms, 5%, 1/4 watt	18470-102
R120	RESISTOR, FIXED, DEPOSITED CARBON: 180K ohms, 5%, 1/4 watt	18470-184
R121	RESISTOR, FIXED, METAL FILM: 28.7K ohms, 1%, 1/2 watt	18525-925
R122	RESISTOR, VARIABLE: wire wound, 10K ohms, printed circuit mtg, 20%, 2 watt	16925-569
R123	RESISTOR, VARIABLE: composition, 1 megohm, 20%, 1/2 watt	40300-105
R124	RESISTOR, VARIABLE: composition, 2 megohms, 20%, 1/2 watt	16925-655
R125	Same as R111	
R126	Same as R106	
R127	RESISTOR, FIXED, COMPOSITION: 2.7 megohms, 10%, 1/2 watt	18415-272
R128	RESISTOR, FIXED, COMPOSITION: 4.7 megohms, 10%, 1/2 watt	18415-472
R129	RESISTOR, FIXED, COMPOSITION: 2.2 megohms, 10%, 1/4 watt	18455 222
R201	RESISTOR, FIXED, DEPOSITED CARBON: 820 ohms, 5%, 1/4 watt	18470-821
R202	RESISTOR, FIXED, DEPOSITED CARBON: 10 ohms, 5%, 1/4 watt	18470-100
R203	Same as R111	
R204	RESISTOR, FIXED, DEPOSITED CARBON: 47 ohms, 5%, 1/4 watt	18470-470
R205	RESISTOR, FIXED, COMPOSITION: 220 ohms, 5%, 1/2 watt	18411-221
R206	RESISTOR, FIXED: 2.7 ohms, 5%, 1/4 watt	18555-85
R207	Same as R103	
R208	Same as R202	
R209	RESISTOR, FIXED, DEPOSITED CARBON: 2200 ohms, 5%, 1/4 watt	18470-222
R210	Same as R107	
R211	RESISTOR, FIXED, DEPOSITED CARBON: 330 ohms, 5%, 1/4 watt	18470-331
R212	RESISTOR, VARIABLE: wire wound, 150 ohms, 20%, 2 watt, printed circuit mtg	16925-574
R213	RESISTOR, FIXED, DEPOSITED CARBON: 150 ohms, 5%, 1/4 watt	18470-151
R214	RESISTOR, FIXED, DEPOSITED CARBON: 75 ohms, 5%, 1/4 watt	18470-750
R215	Same as R103	
R216	RESISTOR, VARIABLE: composition, 100 ohms, 20%, 1/4 watt	16925-616
R217	Same as R214	
R218, R219	RESISTOR, FIXED, METAL FILM: 137 ohms, 1%, 1/4 watt	18555-72
R220	RESISTOR, FIXED, METAL FILM: 576 ohms, 1%, 1/4 watt	18555-76
R221	Same as R202	
R222	RESISTOR, VARIABLE: composition, 500 ohms, 20%, 1/4 watt	16925-627
R223	RESISTOR, FIXED, COMPOSITION: 4700 ohms, 10%, 1/2 watt	18412-472
R224, R225	Same as R114	
R226	RESISTOR, FIXED, METAL FILM: 187 ohms, 1%, 1/4 watt	18555-62
R227	RESISTOR, FIXED, METAL OXIDE: 510 ohms, 5%, 4 watt	18575-539
R228	RESISTOR, FIXED, DEPOSITED CARBON: 220 ohms, 5%, 1/4 watt	18470-221
R229	RESISTOR, FIXED, DEPOSITED CARBON: 4.7 ohms, 5%, 1/4 watt	18555-80
R230	RESISTOR, FIXED: calibration, value determined in production	
R231	RESISTOR, FIXED: calibration, value determined in production	
R232	RESISTOR, FIXED: calibration, value determined in production	
R233	RESISTOR, FIXED, DEPOSITED CARBON: 62 ohms, 5%, 1/4 watt	18470-620
R234	RESISTOR, FIXED, METAL OXIDE: 39 ohms, 2%, 1/2 watt	18610-392
R235	Same as R229	
R236	Same as R234	
R237	Same as R227	
R238	Same as R223	
R239	Same as R228	
R240, R241	Not used	
R242	RESISTOR, FIXED, DEPOSITED CARBON: 100K ohms, 5%, 1/4 watt	18470-104
R243	RESISTOR, FIXED, METAL OXIDE: 51 ohms, 2%, 1/2 watt	18610-512
R244	RESISTOR, FIXED, METAL OXIDE: 510 ohms, 2%, 1/2 watt	18611-512
R245	RESISTOR, FIXED, DEPOSITED CARBON: 2000 ohms, 5%, 1/4 watt	18470-202

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R246	RESISTOR, FIXED, COMPOSITION: 330 ohms, 10%, 1/2 watt	18411-332
R247	Same as R209	
R248	Same as R202	
R249	RESISTOR, FIXED, DEPOSITED CARBON: 200 ohms, 5%, 1/4 watt	18470-201
R250	Same as R114	
R251	RESISTOR, FIXED, DEPOSITED CARBON: 12K ohms, 5%, 1/4 watt	18470-123
R252	RESISTOR, VARIABLE: wire wound, 2K ohms, printed circuit mtg, 20%, 2 watt	16925-568
R253	Same as R119	
R254	Same as R111	
R255	Same as R123	
R256	RESISTOR, FIXED, DEPOSITED CARBON: 220K ohms, 5%, 1/4 watt	18470-224
R257	RESISTOR, FIXED, DEPOSITED CARBON: 5600 ohms, 5%, 1/4 watt	18470-562
R258	Same as R103	
R259	RESISTOR, FIXED, METAL OXIDE: 560 ohms, 2%, 1/2 watt	18611-562
R260	Same as R201	
R261	Same as R204	
R262	Same as R103	
R263	Same as R206	
R264	Same as R209	
R265	Same as R104	
R266	RESISTOR, FIXED, COMPOSITION: 1000 ohms, 10%, 1/2 watt	18412-102
R267, R268	Same as R103	
R269	Same as R104	
R270	Same as R204	
R271	RESISTOR, FIXED, DEPOSITED CARBON: 3900 ohms, 5%, 1/4 watt	18470-392
R272	Same as R119	
R273	Same as R104	
R274	Same as R103	
R275	Same as R119	
R276	Same as R271	
R277	Same as R114	
R278	Same as R202	
R279	Same as R106	
R280, R281	RESISTOR, FIXED, DEPOSITED CARBON: 18 ohms, 5%, 1/4 watt	18470-180
R282, R283	RESISTOR, FIXED, DEPOSITED CARBON: calibration, values determined in production	
R284	Same as R104	
R301	RESISTOR, FIXED, METAL FILM: 990K ohms, 0.5%, 1/4 watt	18555-74
R302	Same as R228	
R303	RESISTOR, FIXED, METAL FILM: 10.1K ohms, 0.5%, 1/4 watt	18555-73
R304	RESISTOR, FIXED, METAL FILM: 1 megohm, 1%, 1/4 watt	18555-35
R305	RESISTOR, FIXED, METAL FILM: 500K ohms, 1%, 1/4 watt	18555-67
R306	RESISTOR, FIXED, METAL FILM: 800K ohms, 1%, 1/4 watt	18555-68
R307	RESISTOR, FIXED, METAL FILM: 900K ohms, 1%, 1/4 watt	18555-69
R308	RESISTOR, FIXED, METAL FILM: 950K ohms, 1%, 1/4 watt	18555-70
R309	RESISTOR, FIXED, METAL FILM: 980K ohms, 1%, 1/4 watt	18555-71
R310	Same as R202	
R311	Same as R204	
R312	Same as R103	
R313	Same as R304	
R314	RESISTOR, FIXED, METAL FILM: 250K ohms, 1%, 1/4 watt	18555-66
R315	RESISTOR, FIXED, METAL FILM: 111K ohms, 1%, 1/4 watt	18555-65
R316	RESISTOR, FIXED, METAL FILM: 52.6K ohms, 1%, 1/4 watt	18555-64
R317	RESISTOR, FIXED, METAL FILM: 20.5K ohms, 1%, 1/4 watt	18555-63
R318, R319	RESISTOR, FIXED, COMPOSITION: 12 megohms, 10%, 1/2 watt	18416-122
R401	RESISTOR, FIXED, HIGH VOLTAGE OXIDE: 500 megohms, 2%, 1/2 watt	18526-25
R402	RESISTOR, FIXED, METAL FILM: 50 megohms, 1%, 1 watt	18550-220
R403	RESISTOR, FIXED, METAL FILM: 5 megohms, 1%, 1/4 watt	18555-75
R404	Same as R305	
R405	RESISTOR, FIXED, METAL FILM: 140K ohms, 1%, 1/2 watt	18526-23
R406	RESISTOR, VARIABLE: 50K ohms, 1/2 watt, part of S401	
R407	RESISTOR, FIXED, METAL FILM: 2.0K ohms, 1%, 1/2 watt	18526-30
R408	RESISTOR, FIXED, METAL FILM: 3.4K ohms, 1%, 1/2 watt	18526-31

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R409	RESISTOR, FIXED, METAL FILM: 5.76K ohms, 1%, 1/2 watt	18526-29
R410	RESISTOR, FIXED, METAL FILM: 13K ohms, 1%, 1/2 watt	18526-32
R501	Same as R106	
R502	Same as R204	
R503	RESISTOR, FIXED, DEPOSITED CARBON: 22 ohms, 5%, 1/4 watt	18470-220
R504	RESISTOR, FIXED, COMPOSITION: 750 ohms, 5%, 1/2 watt	18411-751
R505	RESISTOR, FIXED, DEPOSITED CARBON: 7500 ohms, 5%, 1/4 watt	18470-752
R506	Same as R103	
R507	RESISTOR, FIXED, DEPOSITED CARBON: 1100 ohms, 5%, 1/4 watt	18470-112
R508	Same as R249	
R509	Same as R119	
R510	Same as R106	
R511	Same as R103	
R512	Same as R119	
R513	Same as R249	
R514	Same as R119	
R515	RESISTOR, VARIABLE: wire wound, 50 ohms, 20%, 2 watt	16925-636
R516	RESISTOR, FIXED, DEPOSITED CARBON: 130 ohms, 5%, 1/4 watt	18470-131
R517	Same as R257	
R518, R519	Same as R211	
R520, R521	RESISTOR, FIXED, COMPOSITION: 82 ohms, 10%, 1/2 watt	18410-822
R522	Same as R204	
R523	RESISTOR, FIXED: calibration, value determined in production	
R524	Same as R104	
R525	Same as R503	
R526	Same as R257	
R527	Same as R503	
R528	Same as R104	
R529	RESISTOR, FIXED, METAL OXIDE: 2.4K ohms, 2%, 10 watt.	18575-540
R530, R531	RESISTOR, FIXED, DEPOSITED CARBON: 75K ohms, 5%, 1/4 watt	18470-753
R532	Same as R529	
R533	Same as R103	
R534	Same as R109	
R535, R536	Same as R228	
R537	Same as R103	
R538	Same as R104	
R539	Same as R257	
R540	RESISTOR, FIXED, DEPOSITED CARBON: 2400 ohms, 5%, 1/4 watt	18470-242
R541	Same as R257	
R542	Same as R104	
R543	Same as R229	
R544	Same as R271	
R545	RESISTOR, FIXED, DEPOSITED CARBON: 1500 ohms, 5%, 1/4 watt	18470-152
R546	Same as R271	
R547	Same as R213	
R548	RESISTOR, FIXED, DEPOSITED CARBON: 1200 ohms, 5%, 1/4 watt	18470-122
R549	RESISTOR, FIXED, COMPOSITION: 2000 ohms, 5%, 1/2 watt	18412-201
R550	Same as R103	
R551	Same as R228	
R552	Same as R119	
R553	Same as R505	
R554	RESISTOR, FIXED, DEPOSITED CARBON: 270 ohms, 5%, 1/4 watt	18470-271
R555	Same as R505	
R556	RESISTOR, FIXED, DEPOSITED CARBON: 51 ohms, 5%, 1/4 watt	18470-510
R557	Same as R548	
R558	Same as R106	
R559	RESISTOR, FIXED, DEPOSITED CARBON: 22K ohms, 5%, 1/4 watt	18470-223
R560	Same as R109	
R561	Same as R111	
R562	Same as R209	
R563, R564	Same as R213	
R565	Same as R554	
R566, R567	Same as R109	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R568	Same as R113	
R569	Same as R106	
R570	RESISTOR, VARIABLE: composition, 200 ohms, 20%, 1/4 watt	16925-617
R571	Same as R228	
R572	Same as R202	
R573	RESISTOR, FIXED, COMPOSITION: 100 ohms, 10%, 1/2 watt	18411-102
R601	RESISTOR, FIXED, COMPOSITION: 15 ohms, 10%, 1 watt	18420-152
R602	Same as R228	
R603	Same as R204	
R604	Same as R559	
R605	Same as R503	
R606	Same as R209	
R607	RESISTOR, FIXED, DEPOSITED CARBON: 3000 ohms, 5%, 1/4 watt	18470-302
R608	Same as R222	
R609	RESISTOR, FIXED, DEPOSITED CARBON: 300 ohms, 5%, 1/4 watt	18470-301
R610	Same as R245	
R611	Same as R106	
R612	Same as R257	
R613, R614	Same as R112	
R615	Same as R257	
R616	Same as R106	
R617, R618	Same as R103	
R619	RESISTOR, FIXED, DEPOSITED CARBON: 27K ohms, 5%, 1/4 watt	18470-273
R620	RESISTOR, FIXED, COMPOSITION: 47K ohms, 10%, 1/2 watt	18413-472
R621	Same as R119	
R622	Same as R104	
R623	Same as R228	
R624	Same as R601	
R625	Same as R228	
R626	Same as R204	
R627	Same as R559	
R628	Same as R119	
R629	Same as R204	
R630	Same as R129	
R631	Same as R242	
R632	Same as R559	
R633	Same as R257	
R634	Same as R545	
R635	Same as R103	
R636	Same as R111	
R637	Same as R257	
R638	Same as R106	
R639	Same as R271	
R640	Same as R119	
R641	Same as R211	
R642	Same as R209	
R643	Same as R242	
R644	RESISTOR, FIXED, DEPOSITED CARBON: 1 megohm, 5%, 1/4 watt	18470-105
R645	Same as R245	
R646	Same as R122	
R647	Same as R204	
R648	Same as R104	
R649	Same as R554	
R650	RESISTOR, FIXED, DEPOSITED CARBON: 15K ohms, 5%, 1/4 watt	18470-153
R651	Same as R103	
R652	RESISTOR, FIXED, DEPOSITED CARBON: 910K ohms, 5%, 1/4 watt	18470-914
R653	Same as R242	
R654	RESISTOR, FIXED, DEPOSITED CARBON: 20K ohms, 5%, 1/4 watt	18470-203
R655	RESISTOR, VARIABLE: composition, 100K ohms, 20%, 1/4 watt	16925-663
R656	Same as R106	
R657	Same as R573	
R658	Same as R507	
R659 thru R661	RESISTOR, VARIABLE: wire wound, 500 ohms, 20%, 2 watt	16925-654
R662	RESISTOR, FIXED, DEPOSITED CARBON: 62K ohms, 5%, 1/4 watt	18470-623

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R663	RESISTOR, FIXED, DEPOSITED CARBON: 510 ohms, 5%, 1/4 watt	18470-511
R664	Same as R103	
R665	Same as R114	
R666	Same as R257	
R667	Same as R103	
R668	Same as R209	
R669	RESISTOR, VARIABLE: composition, 250 ohms, 5-1/2 turns, 20%, 1/2 watt	16925-665
R670	Same as R503	
R671	Same as R103	
S101	SWITCH: slide, dpdt	19911-109
S301	SWITCH: rotary (vertical attenuator) 4 section, 12 position	19912-641
S302	SWITCH: slide, single pole, 3 position	19911-108
S401	SWITCH: rotary (sweep) 4 section, 24 position, supplied with 50K variable resistor on rear	19912-642
S601 thru S611	SWITCH: push button, 11 station	19910-204
T101	TRANSFORMER: power	20800-362
T501	TRANSFORMER	20800-363
V101	TUBE: 4" cathode ray, potted	20877-37
	BOOKLET: instructions	2490-594
	KNOB: black, with dot	11505-216
	KNOB: black, with modified ring skirt 1/16" high, with white line on side aligned with dot	11505-217
	KNOB: red, for 1/8" shaft	11505-218
	KNOB: black, with modified ring skirt 1/16" high, with white line on side, for 1/4" shaft	11505-219

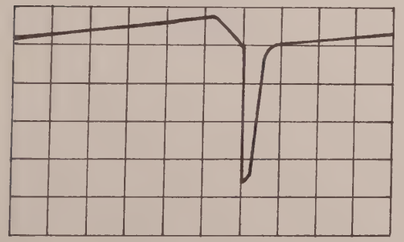


2 m sec/div.

TEST POINT B

20v/div.

(junction of R119 and R118)



2 m sec/div.

TEST POINT C

.05/div.

(junction of R116, R121 and base of Q109)

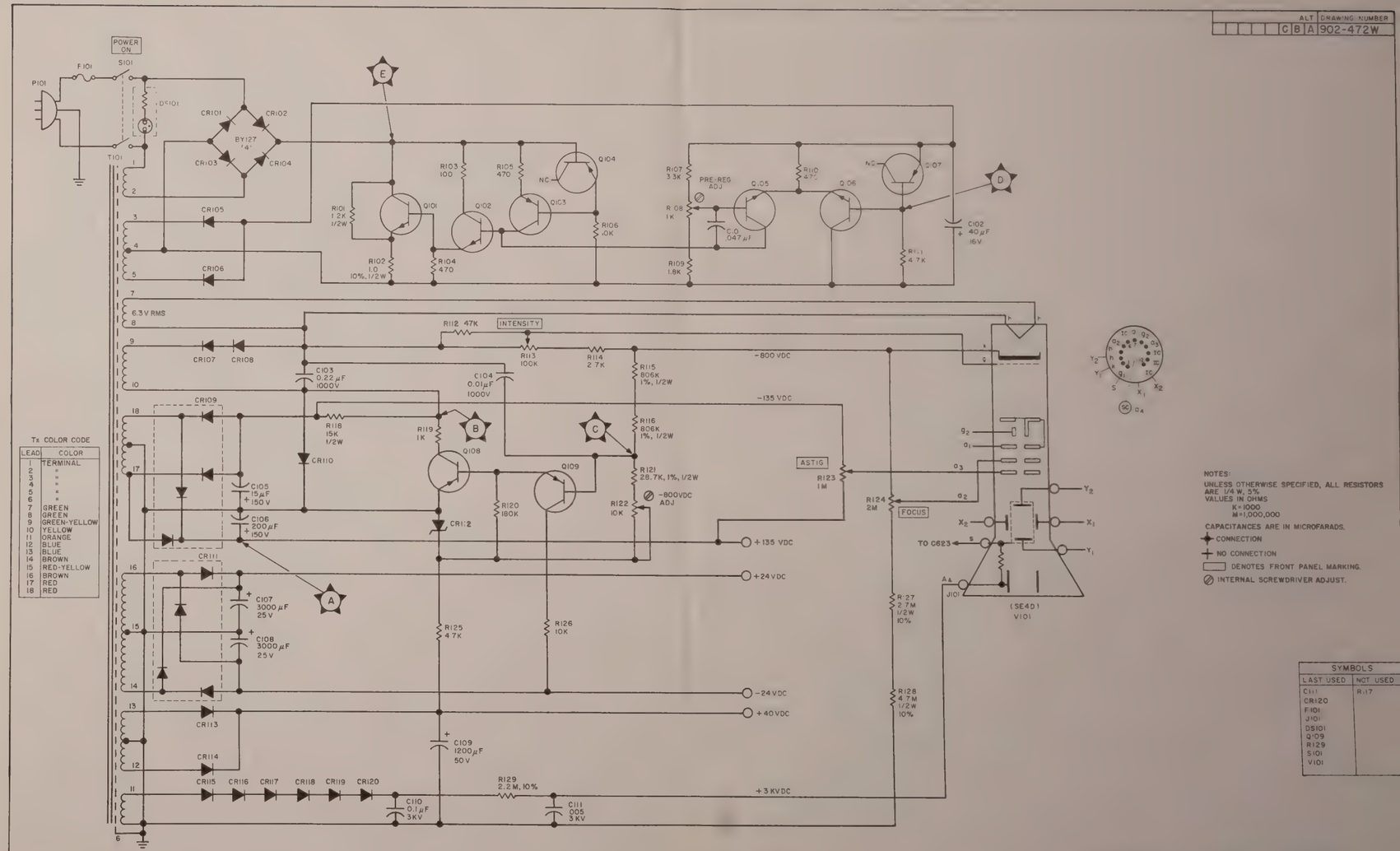
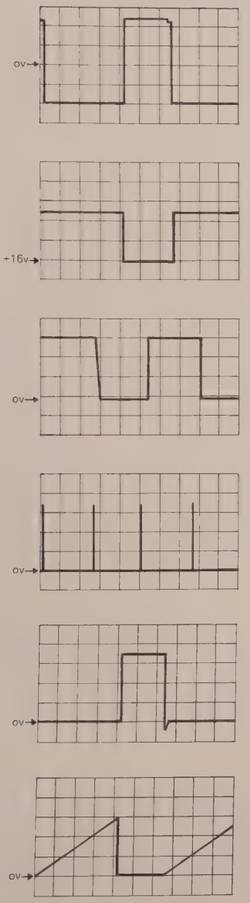


FIG. 26 — SCHEMATIC WIRING DIAGRAM — Model CRO-5000
Sheet 1 of 6



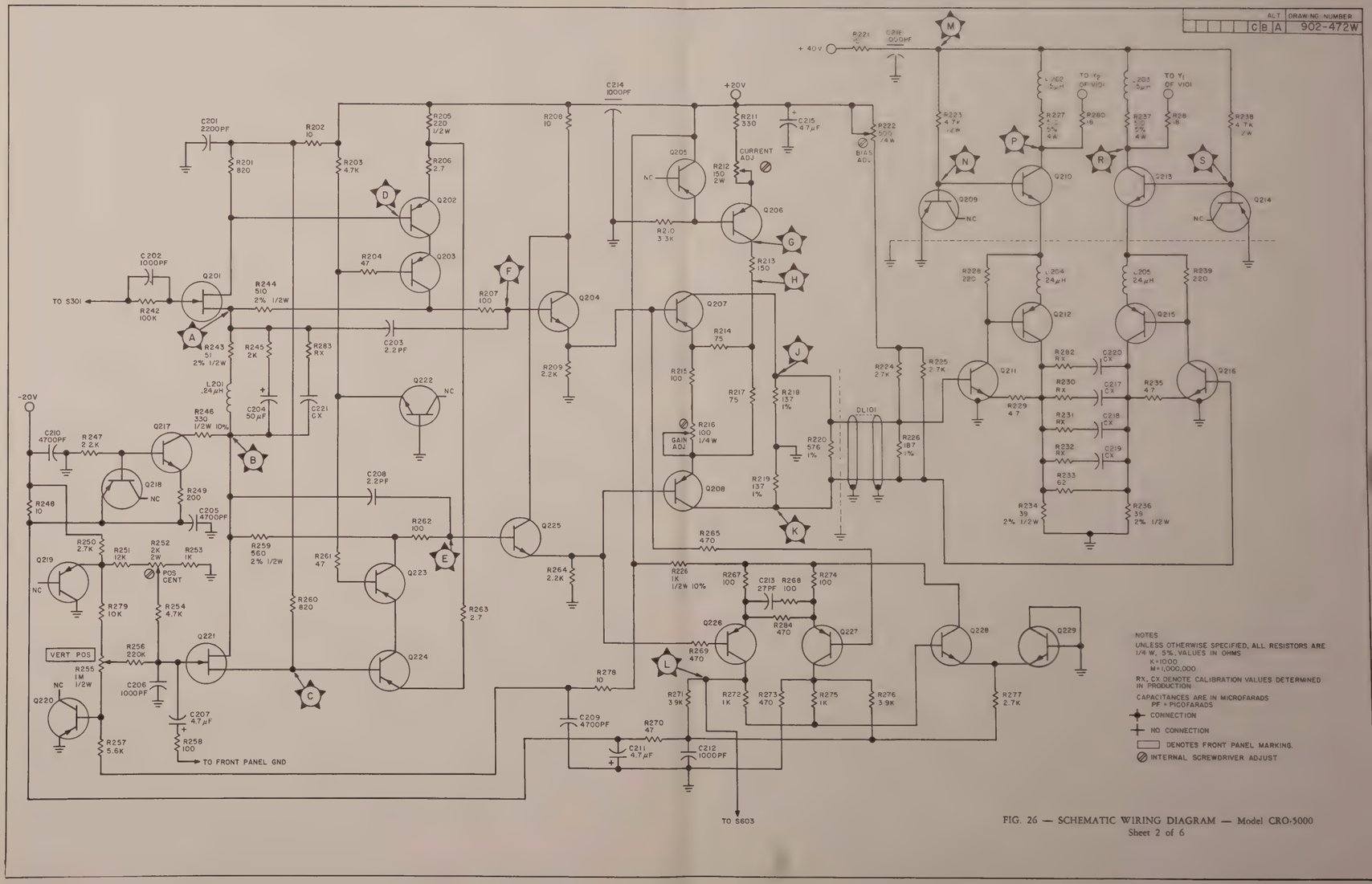


FIG. 26 — SCHEMATIC WIRING DIAGRAM — Model CRO-5000
Sheet 2 of 6

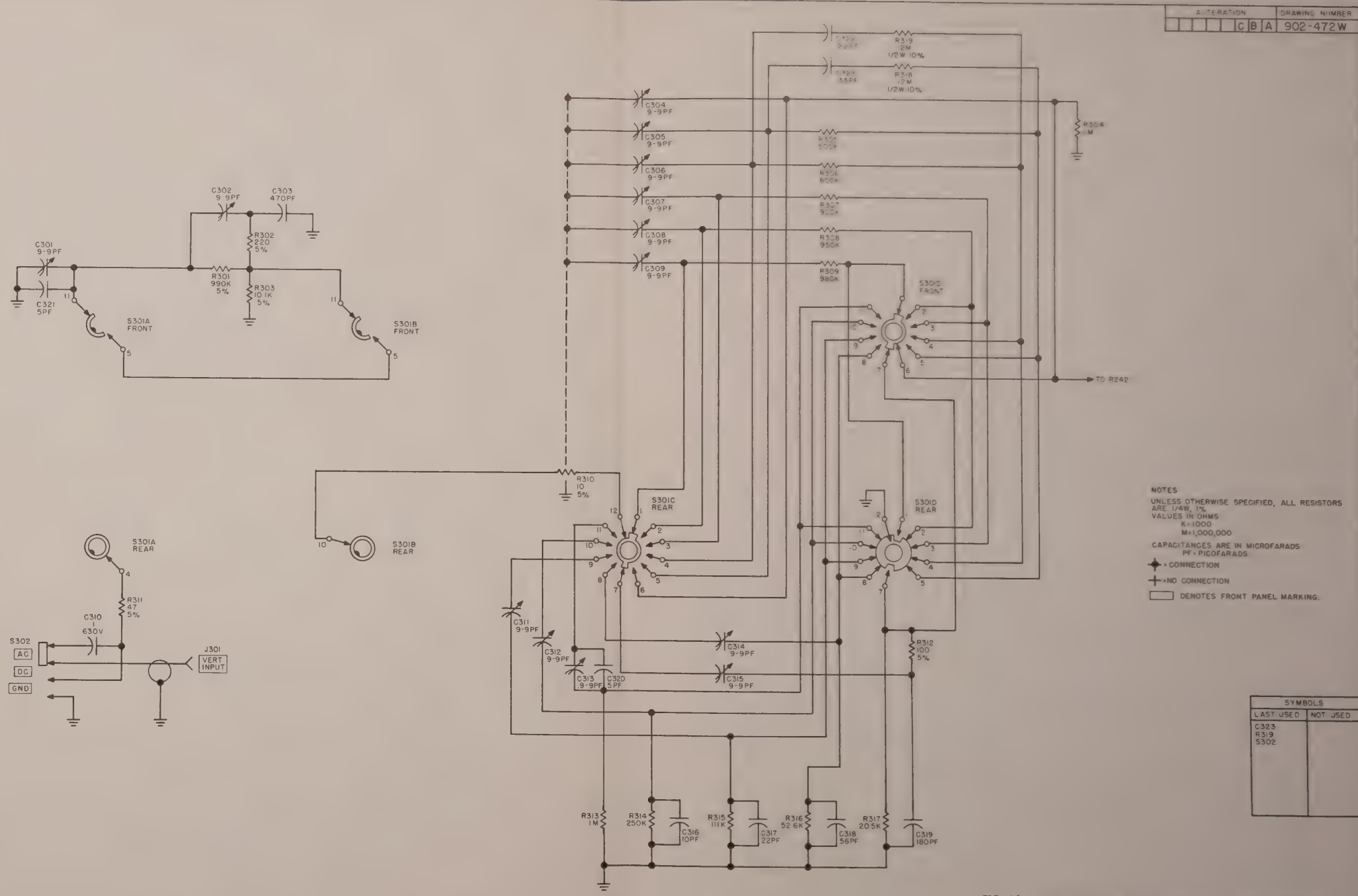
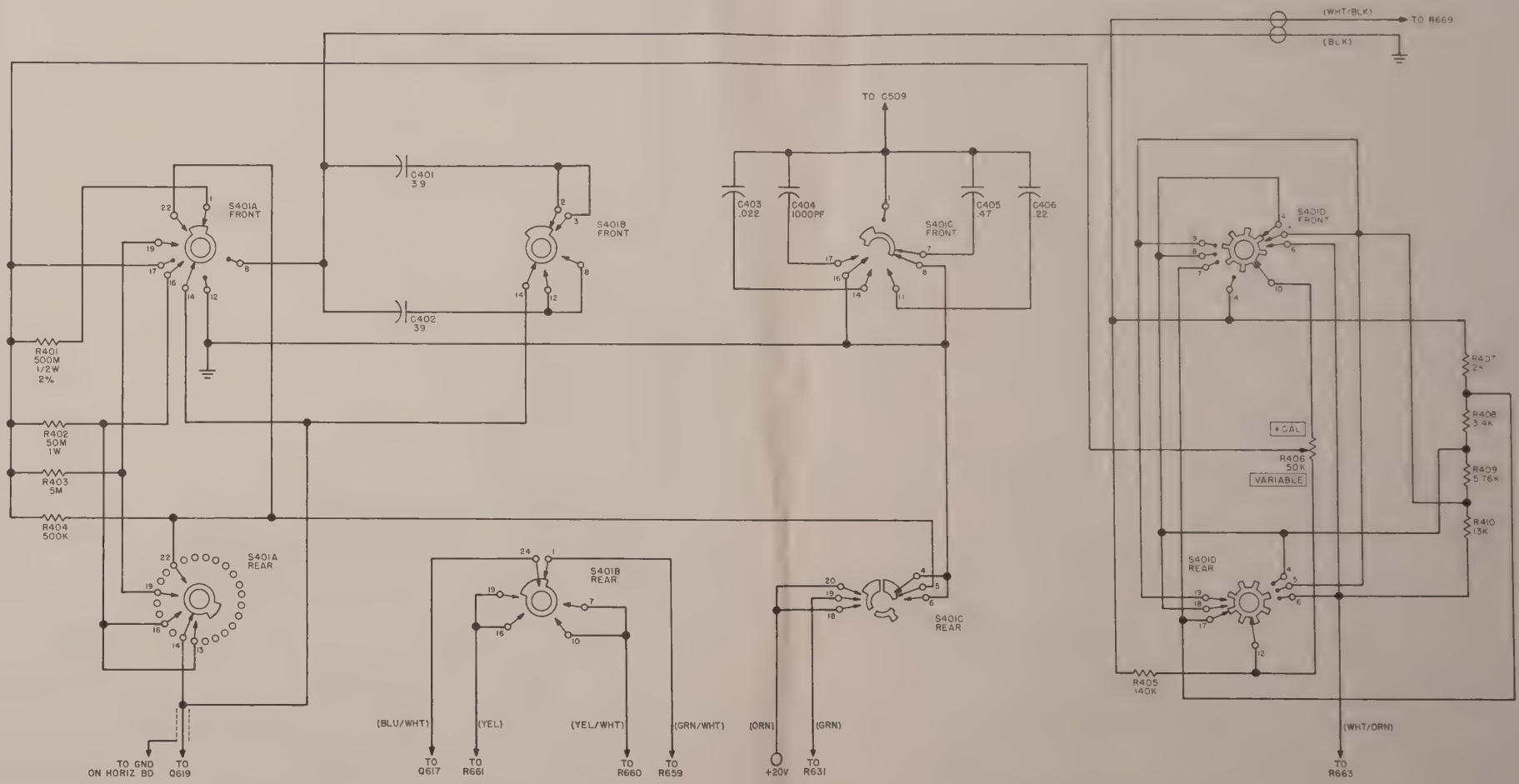


FIG. 26 — SCHEMATIC WIRING DIAGRAM — Model CRO-5000
Sheet 3 of 6

ALTERATION						DRAWING NUMBER
				C	B	A	902-472W



SYMBOLS	
LAST USED	NOT USED
C406 R410	

NOTES

UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/4W, 1%
VALUES IN OHMS
K=1000
M=1,000,000

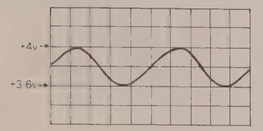
CAPACITANCES ARE IN MICROFARADS
PF= PICOFARADS

+ = CONNECTION

+ = NO CONNECTION

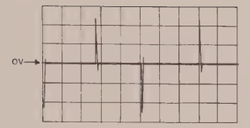
▭ DENOTES FRONT PANEL MARKING

FIG. 26 — SCHEMATIC WIRING DIAGRAM — Model CRO-5000
Sheet 4 of 6



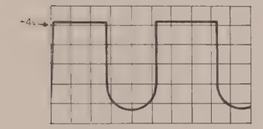
TEST POINT A
TRIGGER LEVEL
MAXIMUM CCW

.2v/div
2 μ sec/div



TEST POINT C
(Slope -)

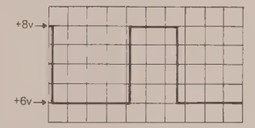
.1v/div
2 μ sec/div



TEST POINT A
TRIGGER LEVEL

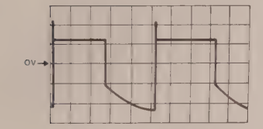
.2v/div
2 μ sec/div

(adjusted for steady
scope presentation)



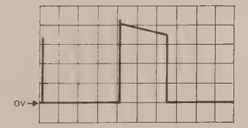
TEST POINT D

.5v/div
20 μ sec/div



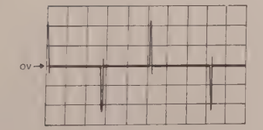
TEST POINT B

.2v/div
2 μ sec/div



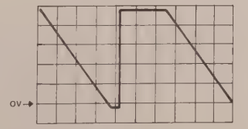
TEST POINT E

.2v/div
20 μ sec/div



TEST POINT C
(Slope +)

.1v/div
2 μ sec/div



TEST POINT F

20v/div
20 μ sec/div

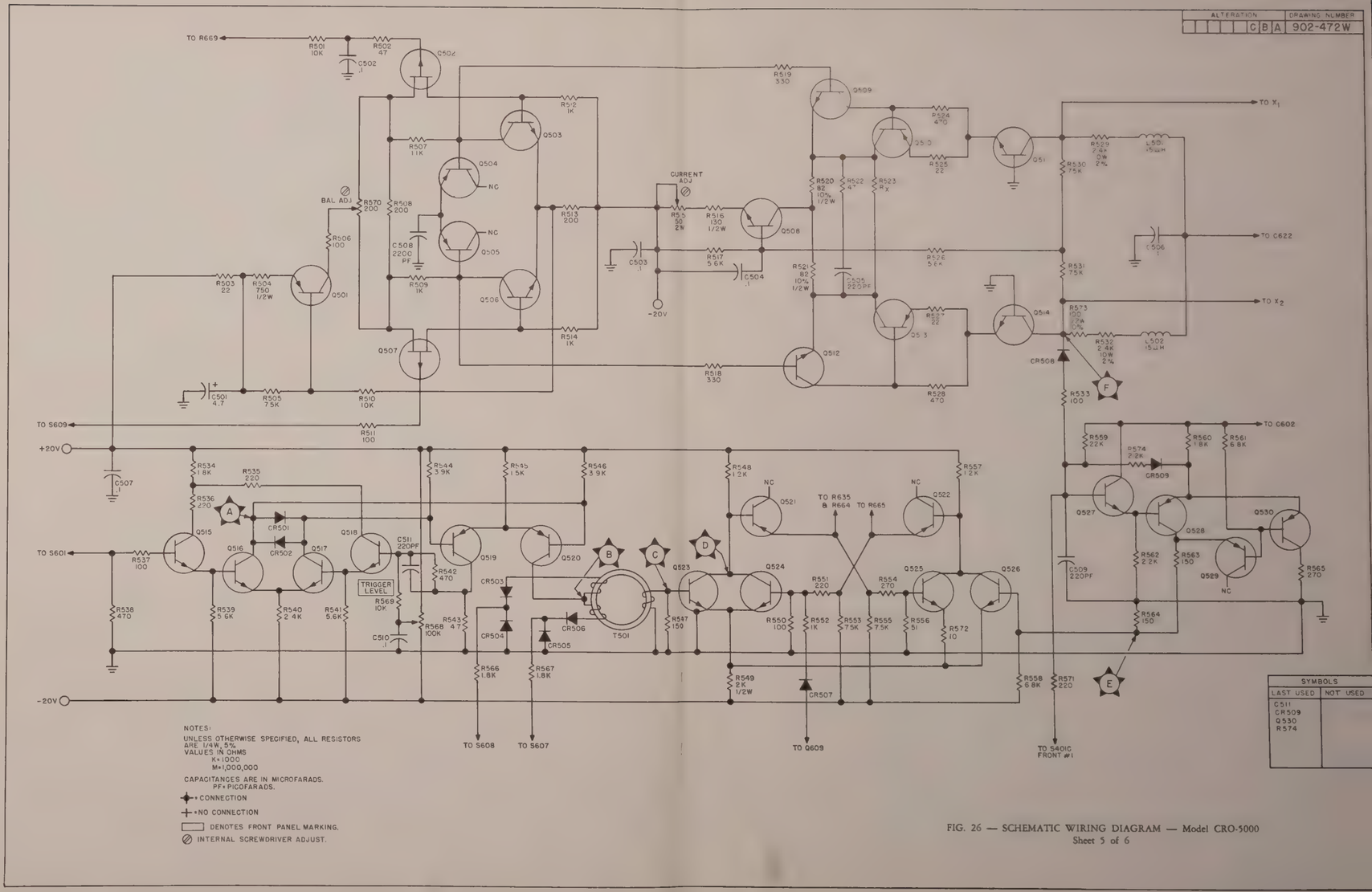
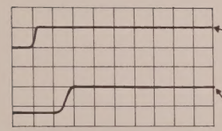


FIG. 26 — SCHEMATIC WIRING DIAGRAM — Model CRO-5000
Sheet 5 of 6



Vertical Test Point Voltages

TEST POINT	VERT POSITIONING CONTROL CW	CCW	
A	+ .300V	+ .335V	
B	- .700V	- .375V	
C	+ 14.0V	+ 13.9V	
D	+ 13.7V	+ 13.8V	
E	+ 3.55V	+ 6.75V	
F	+ 6.75V	+ 3.55V	
J	+ 1.60V	+ 2.50V	
K	+ 2.50V	+ 1.60V	
L	+ 1.50V	+ 1.50V	
M	NA	NA	+ 39V
N	NA	NA	+ 6V
P	+ 34.5V	+ 11.6V	
R	+ 11.6V	+ 34.5V	

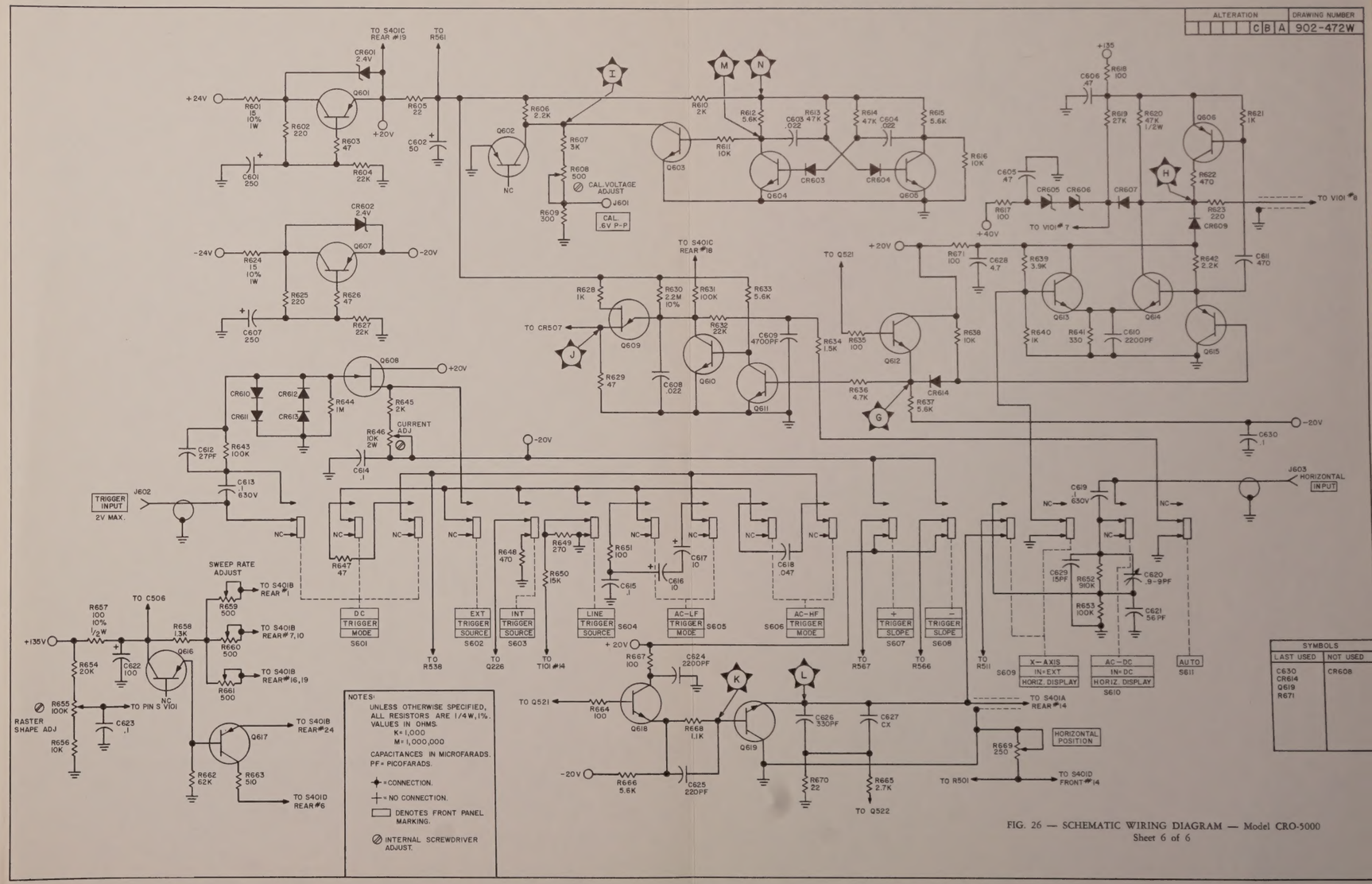


FIG. 26 — SCHEMATIC WIRING DIAGRAM — Model CRO-5000
Sheet 6 of 6